EFFECTS OF EXPOSURE TO NATURE AND PLANTS ON COGNITION AND MOOD: A COGNITIVE PSYCHOLOGY PERSPECTIVE

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EFFECTS OF EXPOSURE TO PLANTS AND NATURE ON COGNITION AND MOOD: A COGNITIVE PSYCHOLOGY PERSPECTIVE

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Two theories posit the restorative benefits of exposure to plants and natural settings, either in the form of stress reduction and improved mood, or through enhancement of cognitive performance, specifically attention processes. Research conducted on the latter area has used a wide variety of tasks to measure attention, often without consideration to underlying cognitive processes. The main purpose of this research was to examine the effects of natural stimuli on cognition and mood from a cognitive science perspective, using measures that assess specific underlying cognitive processes. The secondary objectives of the research were to explore the effect of natural stimuli on subjective well-being and examine whether different types of exposure would have distinct impacts on cognition and mood.

Four experimental studies were conducted in order to examine three exposure types: (1) window views of nature vs. buildings vs. control, (2) plants vs. other embellishments, and (3) two studies comparing the interaction with living plants to viewing pictures of plants. Dependent variables consisted of tasks used in the cognitive sciences to measure underlying cognitive processes of inhibition, working memory, creative problem solving, and sustained attention. Verbal working memory was measured using the Backwards Digit Span task and the *n*-back task. Sustained attention was assessed using a vigilance task. Executive attention processes of inhibition and creative problem solving were measured by the Stroop Task, and either the Remote Associates Test or the Abbreviated Torrance Test for Adults, respectively.

Subjective mood state was examined using the Profile of Mood States – Short Form and the Positive and Negative Affectivity Scale.

Quantitative statistical analyses revealed the use of dependent measures assessing specific cognitive processes produces results different from previous operationalizations of attention employed in other studies. Window views of nature enhanced creative problem-solving performance more than the building view or 'no-view' control, but did not influence sustained attention. Participants exposed to plants versus other office embellishments did not show better performance on a working memory task. In the majority of the studies, mood state was unaffected. Overall, the results suggest that more precise operationalizations of attention are required.

BIOGRAPHICAL SKETCH

In 1993, Debra Rich obtained a BS in Environmental Science with a minor in Natural Resource Management (Forestry) from Rutgers University in New Brunswick, New Jersey. She spent the next four years teaching a variety of environmental and outdoor programs to youth and adults. In 1998, she was admitted to Lesley College in Cambridge, Massachusetts, and in 1999, completed an interdisciplinary MA degree in Agricultural Education. During and after her studies, she was employed at a variety of educational, hydroponic, and organic farms around the state, until 2001, when she accepted a job as the hydroponics greenhouse technician at McMurdo Station, Antarctica. She spent one austral summer and three austral winters, from 2001-2003, in Antarctica, where her PhD ideas blossomed. In 2004, with generous funding provided by NASA, she was accepted to Cornell University to pursue a PhD in Horticulture, with an emphasis on understanding the effects of exposure to plants and nature on cognition and mood.

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When I left the Antarctic to return to graduate school for my Ph.D., I applied to only once place, Cornell University. This was due to the motivating force of Dr. Langhans, who accepted my unique situation and ideas with great enthusiasm, and came out of retirement to help make those thoughts a reality.

Through this connection, I was introduced to the other members of my committee, without whom I could not have hoped to complete my dissertation. I want to thank Dr. Ray Wheeler (and NASA) for providing me with the funding needed to even begin this endeavor, and carry me through three years of work and research. It was also through Dr. Wheeler that I was able to give my first public speaking appearance on the topic of human-plant interactions. I am in deep gratitude to Dr. Don Rakow, who agreed to act as my committee chairman knowing the strange and interdisciplinary nature of my degree. I would also like to thank Dr. Rakow for all of his positive advice and feedback throughout my years at Cornell. I would like to thank Dr. Nancy Wells for the incredible editing and critique of my papers and this dissertation. A huge thanks is extended to Dr. Sonja Skelly for her support of my research and the invitations she extended to me so that I might gain lecturing experience. I would like to thank Dr. Gilovich for helping me understand some of the statistics that were unclear to me after taking courses, for providing feedback for the writing of various research papers, and meeting with me to discuss my future. Finally, I would like to thank Dr. Nancy Rader for helping me to understand the many theories and research studies in the field of cognitive psychology. I am also deeply indebted to Dr. Rader for providing me with connections to professors at Ithaca College with whom I was able to obtain space and participants for two of my research studies. Without this, I would not be completing my dissertation!

In order for me to carry out the various research studies, both at Cornell and Ithaca College, I received the support and generosity of many people. Dr. Carol Bader allowed me use of the Bailey Conservatory. Janet McCue, Kathy Chang, and many people at Mann Library, gave me use of an office space and study room so that I might conduct my third study on window views. They were also very curious and supportive of my efforts! At Ithaca College, Dr. Leigh Ann Vaughn and Dr. Holmes allowed me use of their research spaces to conduct two of my studies, as well as opportunities to recruit participants from their courses.

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LIST OF ABBREVIATIONS

ART: Attention Restoration Theory

ANAM: Automated Neuropsychological Assessment Metrics – a computerized battery of cognitive tasks

ATTA: Abbreviated Torrance Test for Adults – a standardized measure of creativity

BDS: Backwards Digit Span – a working memory task

GSS: Global Seasonality Score – a self-report measure and part of the SPAQ

N – back task: a measure of working memory

PANAS: Positive and Negative Affectivity Scale – a self-report measure of positive and negative affect

POMS: Profile of Mood States – a self-report measure of various mood states, including depression-dejection, anger-hostility, vigor-activity, confusion-bewilderment, fatigue-inertia, and tension-anxiety

PSS: Perceived Stress Scale – a self-report measure of perceived stress

SAD: Seasonal Affective Disorder

SPAQ: Seasonal Pattern Assessment Questionnaire – assesses possible influence of seasons on well-being

S-SAD: Sub-syndromal – Seasonal Affective Disorder

CHAPTER ONE

INTRODUCTION

"Gaze at the beauty of Earth's greenings. Now, think." Hildegard von Bingen

Over thirty experiments in the last twenty years have indicated that exposure to natural stimuli can have a restorative effect on cognition and mood. The most profound observation in examining the research is the positive impact of so many types of exposure to natural stimuli -- even something as simple as having a single plant in the room. In fact, exposure does not always involve direct interaction or contact; a window view of a natural scene seems to provide enough connection to yield at least short-term benefits. Furthermore, beneficial effects on mood and cognition are not just limited to adults; they also extend to adolescents and children.

Within the large body of literature focused on the beneficial effects of nature and plants on cognition and mood, the majority of the research has been conducted in relation to one of the two dominant theories in the field. Those studies concerned with the restorative effects of natural stimuli on attentional processes typically, but not exclusively, fall under Attention Restoration Theory (ART) (Kaplan, S., 1995; Kaplan & Kaplan, 1989). Influences on mood state are often studied in conjunction with the examination of the effects of nature on physiological stress, and are based on Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich, Simons, Losito, Fiorito, Miles & Zelson, 1991).

Since the scientific literature concerning the restorative effects of natural stimuli on well-being and cognitive performance has examined exposure to nature from many perspectives, the definition of what constitutes "natural stimuli" is expansive. In fact, there is no single representation of nature within the literature, not even within the two major theories. For example, operationalizations of natural stimuli have ranged from a single potted plant in an office setting to a completely immersive walk in a nature reserve. Some studies have compared environments containing either natural or urban stimuli (Berto, 2005; Hartig, Mang, & Evans, 1991; Honeyman, 1987; Kuo, 2001), while others have been concerned with the effects of plants versus stimuli such as office adornments (Shibata & Suzuki, 2004; Ulrich, 2004) or a lack of adornment (Lohr, Pearson-Mims, & Goodwin, 1996; Shibata & Suzuki, 2002). An equally broad list of dependent variables exists for measuring mood and cognitive performance.

Attention Restoration Theory and the Cognitive Sciences

With respect to cognitive performance, one of the main challenges throughout the literature is that researchers have often not taken into account underlying cognitive processes such as selection, vigilance, inhibition, or creativity required for task performance. Nor have these processes been definitively linked to the definition and process of attention posited by Attention Restoration Theory (Kaplan, S., 1995; Kaplan & Kaplan, 1989). For example, an "attention task" might or might not involve voluntary or involuntary selective processes, require inhibition, require creative problem solving, make use of working memory, or involve vigilance. What is more surprising is that the tenets of Attention Restoration Theory (ART: Kaplan, 1995; Kaplan & Kaplan, 1989) are directly influenced by work in cognitive psychology, specifically that of William James (1892), but only recently have researchers in the field begun examining effects of natural stimuli using methodologies that integrate Attention Restoration Theory and cognitive psychology. As the findings have been mixed (Berto, 2005; Faber-Taylor, Kuo, & Sullivan, 2002; Kuo, 2001; Kuo & Sullivan, 2001; Laumann et al, 2003), the question arises as to whether it can be concluded that exposure to nature stimuli positively affects cognitive performance.

Additional questions remain concerning what dosage and type of exposure is necessary to yield restoration.

Mood State and Cognition

The influence of nature on positive mood has often been examined from the perspective of Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich et al., 1999). The theory emphasizes that positively-toned emotional states and physiological responses such as lowered blood pressure and reduced heart rate occur when viewing certain natural scenes after a situation involving stress. Findings indicate that, after exposure to a stressor, a reduction in negative emotional states such as fear and anger, and increased positive feelings are observed in participants exposed specifically to unthreatening nature scenes but not urban settings (Hartig et al., 2003; Honeyman, 1987; Ulrich, 1979; Ulrich & Simons, 1986; Ulrich et al., 1991). Interestingly, when individuals are not under stress, the results are less straightforward and seem to vary, depending on the subjective dependent measure employed to quantify influences on mood. Additionally, researchers studying the effects of nature and plants on mood state also have not integrated cognitive tasks, even though cognitive psychologists have found relationships between performance on certain types of tasks and mood state.

Research Questions

The main objective of this research was to integrate research conducted within the tenets of Attention Restoration Theory with methodology and literature from cognitive psychology, and then to evaluate whether a range of types and levels of exposure to natural stimuli affects mood state and specific underlying cognitive processes. We examined the possibility that differences in results of prior studies were due to methodological concerns, specifically with the kinds of tasks chosen to represent directed attention, but which may have been measuring a different cognitive process. Therefore, we used tasks employed in cognitive psychology for measuring processes associated with inhibition, sustained attention, working memory, and creative problem solving. As there are many 'types' or definitions of nature to explore, this research focused on nature that could be encountered in a workplace setting: (1) viewing plants as office embellishments, (2) working directly with plants, (3) viewing pictures of plants, or (4) having a window view of nature. In addition, since comparisons of different types of exposure have yet to be explored in the literature, two of the studies exposed participants to two different types of natural stimuli (i.e. interaction with living plants and pictures of plants) to evaluate whether they would indeed influence cognition and mood differently. Finally, we explored possible influences on mood state and subjective well-being using measures previously administered in earlier research. Within this series of studies, we attempted to answer the following questions:

1. Does exposure to natural stimuli enhance performance on tasks which are used in the cognitive sciences to measure *specific* underlying processes of attention?
2. If directed attention is a type of voluntary attention, and performance on working memory tasks is influenced by voluntary attentional capacity, does the restoration of directed attention from exposure to natural stimuli enhance performance on working memory tasks? In cognitive psychology, there is a relationship between voluntary attention and working memory; therefore, it is possible that working memory is also affected by exposure to natural stimuli.
3. Is mood state enhanced by exposure to specific types of natural stimuli?
4. Do varied types of exposure to natural stimuli influence cognitive performance and mood differently?

CHAPTER 2

LITERATURE REVIEW

THEORIES IN PLANT-HUMAN INTERACTIONS

Two theories dominate the plant-human interaction field, one focusing on nature's role in cognitive functioning, primarily in the restoration of attention (Attention Restoration Theory: Kaplan, S., 1995; Kaplan & Kaplan, 1989) and the other on restorative effects of nature on mood state and physiology in the face of physiological and psychological stress (Psycho-Evolutionary Theory: Ulrich, 1983; Ulrich et al., 1991). Both theories are evolutionarily based; the difference between the two lies principally in the description of the proposed mechanisms behind nature's restorative influence. Attempts have been made to reconcile the two viewpoints (Hartig & Evans, 1993; Kaplan, S., 1995), and research studies have been conducted that endeavor to integrate both perspectives (Hartig et al., 1991, Hartig et al., 2003; Laumann et al., 2003) but with mixed results. In the two studies by Hartig and colleagues (1991; 2003), natural stimuli positively influenced task performance but did not completely influence physiological measures, but the study by Laumann et al. (2003) failed to observe differences between a natural and urban condition on a selective attention task although exposure to natural stimuli did reduce heart rate as compared to participants viewing urban stimuli.

It seems that part of the reason for differences in findings related to attentional processes is that researchers have used a myriad of tasks, some of which were not originally designed for testing the underlying processes associated with attention. In addition, some of the research relating to Attention Restoration Theory (Kaplan, S., 1995; Kaplan & Kaplan, 1989) has not been designed using methodology from cognitive psychology, the foundation on which much of the theory is based. Recent advancements in the study of attention in the cognitive sciences indicate distinct but interrelated processes associated with attention, some of which are just beginning to be incorporated into research concerning nature's influence (Berto, 2005; Faber-Taylor, Kuo, & Sullivan, 2002; Kuo, 2001; Kuo & Sullivan, 2001; Laumann et al., 2003). As each of these studies measured a different attentional process, a few questions arise. First, which processes of attention are positively influenced by exposure to nature and plants? What tasks have been used to measure attention in the past and what do the findings indicate about the influence of natural stimuli on attention? Finally, what type of dependent measures should be utilized in the future to determine nature's influence on attention processes?

Similarly, studies of nature's influence on positive mood have also used various measures, with different results. With a recent (and partial) exception (Hartig, Nybeg, Nillson, & Gärling, 2006), cross-sectional studies mainly find that nature does not positively influence self-report of mood (Kuo & Sullivan, 2001; Tennessen & Cimprich, 1995; Tooley et al., 2006). However, positive mood is observed to increase in longitudinal and pre-post studies when participants are exposed to some type of nature condition (Barnicle & Midden, 2003; Hartig et al., 1991; Hartig et al., 2003; Laumann et al., 2003; Ulrich, 1981; Ulrich et al., 1991) regardless of whether participants are placed under stress prior to the exposure. Recent work provides support for this phenomenon, suggesting differences in the speed at which individuals process affective stimuli when exposed to pictures of natural and urban settings (Hietanen & Korpela, 2004; Korpela, Klemittilä, & Hietanen, 2002). In addition, findings from cognitive psychology indicate that both positive and negative emotions impact attention, creative problem solving, and working memory. Taken as a whole, these findings lead to more questions. Does exposure to nature and plants elicit changes in positive affect and mood regardless of the type of nature exposure or the kind of self-report measure used? Is the change in positive mood enough to also impact cognition? Or put another way, does positive affect and mood mediate the effects of nature/plants on cognition?

Attention Restoration Theory

Attention Restoration Theory (ART) (Kaplan, 1995; Kaplan & Kaplan, 1989) is a cognitive theory based primarily on William James' (1892) insights into attention. James separated attention into two distinct components -- involuntary and voluntary attention. Involuntary attention is passive, whereby an object or idea draws one's focus without effort. Voluntary (or directed) attention, on the other hand, requires effort. In order to purposefully attend to an object, one must focus on it while inhibiting all other stimuli. In an article on Attention Restoration Theory, Stephen Kaplan defined directed attention as a mechanism with the following properties: "…it requires effort, plays a central role in achieving focus, is under voluntary control (at least some of the time), is susceptible to fatigue, and controls distraction through the use of inhibition" (Kaplan, 1995, p. 170). Since mental effort is required to pay attention, an individual's directed attention can become fatigued and require restoration. Kaplan and Kaplan (1989) believe that many everyday activities require directed attention and that certain environments provide the opportunity for restoration of directed attention by engaging involuntary attention. One such environment is nature.

Kaplan and Kaplan (1989) posit that nature contains four components essential for eliciting a restorative experience. These are "…psychological distance from routine mental contents (*being away)* in conjunction with effortless, interest-driven (involuntary) attention *(fascination),* sustained in coherently ordered environments of substantial scope *(extent)* when the person's inclinations match the demands imposed by the environment as well as the environmental supports for intended activities *(compatibility)*" (described in Hartig et al., 2003, p. 110). All four components need to be found in reassuring and safe environments where mental fatigue and stress can be dealt with and focus can be redirected.

In addition, fascination can be broken down into a 'hard' and a 'soft' form. Some environments, for instance, are so compelling that the resulting fascination completely engages the mind and demands attention and focused thought possibly leading to action. This would be considered 'hard' fascination. From an evolutionary standpoint, 'hard' fascination was extremely important for survival – charging animals or angry snakes demand attention and reaction. 'Soft' fascination, on the other hand, which may be engaged by natural scenes, leaves room in the mind for reflection and contemplation (Herzog, Black, Fountaine, & Knotts, 1997; Kaplan & Kaplan, 1989). A window view of a forest or a walk in a natural area presents engaging environments, but do not *demand* attention and physical response. Kaplan and Kaplan believe that this lack of demand of attention resources allows restoration, and the level of restoration obtained from exposure to natural settings varies depending on the obtainment of the following successive levels: conscious clearing of the mind, attention recovery, and reflection.

Psycho-Evolutionary Theory

Ulrich's Psycho-Evolutionary Theory (Ulrich, 1983; Ulrich et al., 1991) is based primarily on the stress-reducing influences of exposure to nature. From an evolutionary standpoint, the theory asserts that acquiring the capacity to engage in rapid restorative responses to threats and challenges had survival advantages for early humans. The theory emphasizes that positively-toned emotional states and physiological responses such as lowered blood pressure occur when viewing certain natural scenes after a situation involving stress. Ulrich and colleagues (Ulrich et al, 1991) postulate that "immediate, unconsciously triggered and initiated emotional responses – not ‘controlled’ cognitive responses – play a central role in the initial level of responding to nature” (p. 207). As an example, when humans are initially under threat, they tend to have increased heart rate and blood pressure. In order to function effectively in an environment that may pose constant threats, humans must have adapted the ability to lower heart rate and blood pressure quickly. Therefore, not only can restoration from natural scenes occur within minutes (Ulrich et al., 1991), it also can occur without conscious cognitive awareness. Unthreatening natural scenes provide a relaxing and safe environment where these reactions can be rapidly ameliorated. Ulrich and Parsons (1992) conclude that natural scenes “foster restoration from stress apparently because of a combination of beneficial effects. They produce increases in positive feelings; reduce negatively toned or stress-related feelings such as fear, anger, or sadness; hold interest/attention effectively and hence may block or reduce stressful thoughts; and elicit positive changes across different physiological systems” (p. 102).

COGNITIVE PSYCHOLOGY OF ATTENTION AND EMOTION

Attention

Cognitive psychological research on attention, including Attention Restoration Theory, is founded in the work of William James (1892), and his division of voluntary and involuntary processes. In the current cognitive psychology literature, voluntary and involuntary attention are also labeled as endogenous versus exogenous attention, or controlled versus automatic attention, respectively. Endogenous, or voluntary attentional control, appears to be a top-down or goal-directed process, and is consciously initiated. On the other hand, exogenous, involuntary (automatic) control is pre-conscious, and can be either a bottom-up, stimulus driven process (Godijn & Theeuwes, 2003) or involve top-down processing when exogenous (or involuntary) cues are related to the central (voluntary) cue (Folk, Remington, & Johnson, 1992; Remington, Folk, & McLean, 2001). Attention research provides strong evidence to support differences between voluntary and involuntary attention (Jonides, 1980, 1983; Posner & Snyder, 1975; Posner, Cohen, & Rafal, 1982; Warner, Joula & Koshino, 1990). Findings are based on the use of 'cueing' tasks, whereby participants are asked to direct their attention to an area of the screen and respond when a cue, or visual signal, is presented in the proper area. However, cues often appear in the periphery of the targeted area as distractors, thereby increasing the amount of time needed to respond once the cue is presented in the target area. Though early research associated the engagement of involuntary attention with the peripheral cues and voluntary attention with a central cue (see Jonides, 1981), more recent evidence suggests peripheral cues are not necessary for engaging involuntary attention (see Prinzmetal et al., 2005). Indeed, it appears that the distinction between voluntary and automatic processes involves more subtle levels or grades (Kahneman & Treisman, 1984).

The question of what engages involuntary attention is still debatable (Rauschenberger, 2003), although research indicates it requires attentional capture, or an involuntary shift of attention due to a compelling environmental cue (Rauschenberger, 2003). In attentional capture experiments, the majority of findings indicate that involuntary attentional shifts occur from abrupt onset, or unexpected, visual stimuli (Lambert, Spencer, & Mohindra, 1987; Theeuwes, 1991b; Warner, Juola, & Koshino, 1990), but some studies find that this shift can be overcome when strong voluntary attention is successfully focused on an area (Peterson, Kramer, & Irwin, 2004; Yantis & Jonides, 1990). In fact, the contingent involuntary orienting hypothesis (Folk et al., 1992) states that involuntary orienting to a cue is contingent on the task-relevant properties of the attentional set. For example, if a distracting cue is similar to the task-relevant cue, participants will involuntarily focus their attention on it. But if the distracting cue is irrelevant to the given task, participants are able to block out the distraction and focus on the relevant task cues. However, other researchers argue that capture is dependent on the type of search strategy employed. One group of researchers hypothesized that the varied findings are due to methodological differences (Ruz & Lupiáñez, 2002), but it may be that voluntary and involuntary attention are controlled by different mechanisms (Fu, Caggiano, Greenwood, & Parasuraman, 2005; Prinzmetal et al., 2005). For example, Prinzmetal and colleagues (2005) used a spatial cueing task where participants engage in the detection task with a peripherally presented stimulus. However, prior to when the stimulus appears, participants are pre-cued to either the location of the stimulus (valid trial) or in a non-target location (invalid trial). When this cue is informative about where the target will occur, it uses voluntary attention. However, when the cue is uninformative and merely a distraction, it invokes involuntary attention as a reflexive mechanism. The findings of the study showed that voluntary attention affected accuracy and reaction time performance on the task, but involuntary attention only affected the reaction time. The researchers suggested the difference was due to the fact that voluntary attention enhances perceptual representations of the stimulus due to the fact that the visual system gathers more information from an attended source than an unattended one, and involuntary attention only affects the decision process relating to location response choice.

Beyond the concept of voluntary and automatic control of attention, Posner and Peterson (1990) have introduced the notion that *sources* of attention form a specific system of anatomical areas, called the attention system. The attention system contains three independent but interrelated networks that carry out functions of alerting, orienting, and executive control. *Alerting* is defined as achieving and maintaining an alert state, *orienting* is the selection of information from sensory input, and e*xecutive control* is defined as monitoring and resolving conflict between computations occurring in different brain areas (Botwinick, Braver, Barch, Carter, & Cohen, 2001). Executive control is also related to upper-level processes requiring mental effort such as filtering, concentration, and inhibition, and is involved in controlling the orienting network (Fuentes, 2004). As the definition implies, executive control requires voluntary attention. However, it appears that alerting and orienting of attention, both of which rely on the visual system, can occur with or without voluntary, conscious control. In fact, research on overt orienting and eye movements (called saccades) has found that saccades are initiated by both voluntary (central) and involuntary (peripheral) cues and that saccades towards exogenous cues often occur without conscious awareness (McCormick, 1997).

Working Memory

Though many models of working memory pepper the literature (Miyake & Shah, 1999), the dominant model of working memory (Baddeley, 2003; Baddeley & Hitch, 1974) is a multi-component model comprised of a central executive (or controlling) system, two slave systems called the visuo-spatial scratch pad and the phonological loop, and an episodic buffer shown in Figure 1 (Baddeley, 2003). In the working memory model, the central executive functions like a 'limited-capacity attentional system capable of selecting and operating control processes and strategies' (Baddeley, 2003, p. 77). This description is similar to that of the role of the executive control component of attention, which has been defined as the reduction of conflicts in processing (Cohen, Aston-Jones, Gilzenrat, 2004). Indeed, other researchers assert that the working memory system contains the contents of short-term memory and controlled attention and that maintaining activation of working memory (for attention demanding tasks) involves the central executive (Engle, Laughlin, Tuholski, & Conway, 1999). Baddeley (2003) also proposes that the central executive corresponds to the supervisory activating system proposed by Norman and Shallice (1986). Engle, Tuholksi, Laughlin, and Conway (1999) draw a parallel between the central executive and what Posner and Snyder (1975) refer to as controlled attention. Additional evidence in the cognitive neuroscience literature links both working memory and the executive control component of the attention system to the prefrontal cortex and the anterior cingulate cortex (Braver, 1997; Gray, Braver, & Raichle, 2002; Posner & Peterson, 1990; Smith & Jonides, 1995), implying from another perspective that the two systems may be related to some degree.

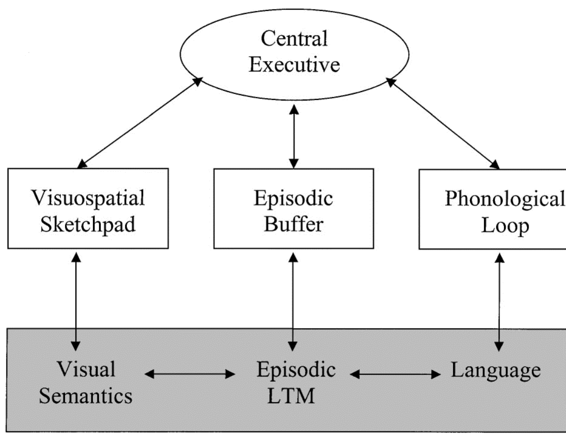

Figure 1. Working Memory Model

Research evidence supports the theoretical link between working memory and attention. If working memory relies on limited (controlled) attentional capacity, then increasing the load on a working memory task should utilize most of that capacity, and hence, limit performance on an additional attention task. By this conceptualization, however, loading memory should create no attentional deficit on an involuntary attention task. Jonides (1981) found that when a concurrent memory load was imposed on participants, peripheral cues (engaging involuntary attention) produced attentional benefits, but effectiveness of central cues (to engage controlled attention) was attenuated. Two studies by Lavie and colleagues found that the higher the working memory load, the harder it is to avoid irrelevant distractors and maintain visual selective attention, a task required controlled attention (de Fockert, Rees, Frith, & Lavie, 2001; Lavie, Hirst, de Fockert, & Viding, 2004). A recent series of experiments by Lavie and de Fockert (2005) also suggests working memory provides goal-directed control of visual selective attention. Indeed, other researchers have found that peripheral items relevant to the current task, or a match to active contents in working memory, evoke involuntary shifts of attention (Downing, 2000; Pratt & Hommel, 2003).

Creative Problem Solving

Flexible cognitive processes regarded as fundamental to the creative ability to solve problems are considered another form of executive processing. Tasks requiring creativity have been found to activate areas of the brain similar to these of other executive attention processes: the pre-frontal cortex and anterior cingulate (Posner & Peterson, 1990). Tasks measuring creative problem solving are usually association tests such as the Remote Associates Task (Bowden & Jung-Beeman, 2003) or the Wisconsin Card Sort Test (Psychological Testing Resources, 2003). Although little research has been conducted on the relationship between creative problem solving ability and brain structures, a great deal of literature provides evidence for a relationship between positive affect and creative task performance (for review, see Ashby, Isen, & Turken, 1999).

Emotion and Cognition

Emotion and cognition are two distinct but inter-related components of human functioning (Martin & Clore, 2001). Indeed, evidence of interaction between the two abounds, although the nature of the interaction is not entirely understood or agreed upon. However, in most of the literature regarding the relationship between cognition and mood, emotion is most often linked to a person's goals (Compton, 2003; Gray, Braver, & Raichle, 2002), with goal relevance leading to preferential processing. Although the goals may differ for each individual, certain commonalities do exist. For example, from an evolutionary perspective, emotional significance might favor responses that lead to the success and survival of the organism (Compton, 2003). Indeed, approach and avoidance cognitive behavior has been linked to emotional state, though most of the research in this area concerns unconscious processing of negative fear-relevant stimuli such as angry faces or spiders (Compton, 2003; Dolan, 2002).

Since processing of stimuli inevitably involves cognition on some level, it is not surprising that attention is influenced by emotional state or emotional stimuli. In a review of the relationship between emotion, cognition, and behavior, Dolan (2002) suggests the processing of emotional stimuli is pre-attentive, and once these stimuli are processed, they can enhance attention in the form of stimulus detection. Both categorical negativity theory (Pratto & John, 1991) and the evolutionary threat hypothesis argue that enhancing attentional awareness would be beneficial for survival, as automatic evaluation of negative stimuli would allow an organism to respond more quickly to threat (see Schimmack, 2005). However, others argue that responses to affective stimuli are not based only on an evolutionary survival mechanism - because they elicit arousal, people attend to the more intrinsically fascinating stimuli in their environment, regardless of whether it is threat-based or not (Lang, 1995). Indeed, one study found that attentional interference was greater when participants were shown pictures that invoked high arousal and valence than low arousal (Schimmack, 2005), regardless of the type of emotional valence. Buodo and colleagues (2002) also found reduced reaction times when participants were shown threat-related stimuli (as opposed to neutral or positive stimuli), but that valence was an important factor, regardless of the intensity of the emotional content of the stimuli.

For example, erotic stimuli reduced reaction times more than other positive stimuli (i.e. sports games), and blood/injury-based stimuli both reduced reaction times more than other types of threat-based stimuli. Regardless of the mechanism behind the effects of emotion on attention, overall, the literature suggests that selective attention and executive control are influenced by emotionally relevant stimuli, with attention biased by individual differences and personal relevance (for review, see Compton; 2002).

Since Attention Restoration Theory posits a positive influence of nature on the restoration of attention and Psycho-Evolutionary theory contends that exposure to nature enhances positively-toned mood states, it is important to look specifically at the relationship between positive affect/mood and cognition. Studies of the effects of positive affect on attention have focused mainly on executive processes. Research examining the effects of positive affect on the *executive control* network of the attention system has shown mixed results. For example, Phillips, Bull, Adams, & Fraser (2002) found that positive affect impaired performance in the switching condition of the Stroop task, where participants had to switch between color naming and word reading, but Kuhl and Kazen (1999) noted a reduction in Stroop interference under positive affect induction. Another set of researchers concluded that positive affect influences cognitive control in specific way, and that the cognitive flexibility associated with increased positive affect leads to reduced perseveration but greater distractibility (Dreisbach & Goschke, 2004).

Though effects on executive control are not straightforward, more than twenty-five experiments, using an array of tasks measuring cognitive flexibility, have found that small inductions of positive affect are effective in significantly enhancing performance on tasks requiring creativity. Inducing positive affect has been found to enhance performance on tasks involving word association (Isen, Johnson, Mertz, &

Robinson, 1985; Isen, Daubman, & Nowicki, 1987), word fluency (Bryan & Bryan, 1991; Green & Noice, 1988; Hirt, 1996), and creative problem solving (Estrada, Isen, & Young, 1994; Isen et al., 1987). Indeed, some researchers suggest that positive emotions broaden the scope of attention, leading to more global processing of stimuli (Fredrickson, 2001; Fredrickson & Branigan, 2005).

However, others (e.g., Melton, 1995) have argued that positive moods lead people to expend less cognitive effort, resulting in poor performance on certain tasks. A study by Kaufmann and Vosburg (1997) found induced positive affect led to poorer performance on a creative task, and negative mood facilitated performance. In a follow-up study by Vosburg (1998) assessing the impact of positive and negative affect on creative tasks requiring divergent thinking, the author found that positive mood was correlated to greater performance on the tasks. More specifically, the author found that problem-finding and problem-solving tasks requiring a satsificing approach (Simon, 1947) were related to better positive mood. However, the researcher did not manipulate mood state prior to administration of the task; the mood scores were based on dispositional self-reports of mood.

Since working memory involves controlled attention and executive processing, it makes sense that emotional stimuli exerting influence on attention would also affect working memory. Interestingly, induced positive and negative emotional states have opposite effects on verbal and spatial working memory. While negative emotional states impair verbal working memory but improve spatial working memory, the opposite pattern emerges for pleasant emotional states (Gray, 2001). A neuro-imaging study confirmed the crossover interaction between emotion and working memory types (Gray, Braver, & Raichle, 2002). Moreover, Gray (2001) found that the stronger the self-reported emotional state of the participants, the greater the influence on cognition, suggesting a higher degree of integration between emotion and cognition than what previously has been suggested.

RELATING COGNITIVE SCIENCE TO PLANT-HUMAN INTERACTIONS

The basic tenets of Attention Restoration Theory have their foundations in the cognitive psychological work on attention by William James. Indeed, S. Kaplan's (1995) definition of directed attention corresponds to what cognitive psychologists refer to as voluntary, or controlled, attention. Both require effort and are under voluntary control. Kaplan goes on to say directed attention is used to control distraction through the use of inhibition. This concept is parallel to the executive control component of the attention system. In addition, Kaplan believes directed attention can become fatigued and require restoration. In this sense, it is the *capacity* of directed attention that is a limiting factor. In the attention literature, the question as to the limits of voluntary attention has been raised. For example, capacity theory (Kahneman, 1973), posits that individuals have a limited pool of cognitive resources used for recognizing and categorizing stimuli and that attention processes are used to regulate these resources. Studies by Posner and colleagues (Posner, 1980; Posner & Boies, 1971) support this assertion, finding that as long as the demand on cognitive resources does not exceed the attentional capacity, individuals can process competing or complex stimuli. In addition, a closely related area of cognitive psychology concerning working memory does posit the idea of a limited-capacity attentional system (Baddeley, 2003) associated with the executive control component of the attention system.

A few questions arise from the theoretical parallel between directed attention in ART and controlled attention. First, is there quantitative evidence supporting nature's restorative influence on directed (voluntary, controlled) attention? Or, put another way, are nature and/or plants compelling enough to engage involuntary attention, allowing for disengagement, and hence, restoration of directed attention? In the attention literature, examination of involuntary attention engagement uses visual cues such as arrows or color changes, but no study has yet attempted to design peripheral or non-informative cues of flora. Studies in the plant-human interaction literature have found that participants do perform better on tasks requiring directed, controlled attention if they have a window view of nature versus a built view (Tennessen & Cimprich, 1995) or green space and trees nearby home (Faber-Taylor, Kuo, & Sullivan, 2002, Kuo, 2001; Kuo & Sullivan, 2001; Wells, 2000). In pre-post studies, participants also showed improvements in tasks requiring directed attention if they viewed nature pictures but not urban pictures (Berto, 2005) or went on a wilderness vacation as opposed to a non-wilderness vacation or no vacation at all (Hartig et al., 1991). These findings imply that exposure to nature engages involuntary attention, allowing for restoration of controlled, directed attention, thus allowing for better performance on a task requiring controlled attention. However, studies of whether nature actually *engages* involuntary attention, especially when directed attention is focused elsewhere, have yet to be conducted. Since Attention Restoration Theory contends that natural settings must be, among other characteristics, fascinating enough to engage involuntary attention, it appears that this area of the theory still has not been conclusively supported.

Of the research that has been conducted, it is only recently that studies examining the effects of exposure to nature and plants on cognition have incorporated cognitive tasks widely used by cognitive psychologists to measure specific underlying cognitive processes. Laumann et al. (2003) and Berto (2005) have utilized tasks measuring voluntary and involuntary selective attention (flanker task), and sustained attention (vigilance task), respectively. Shibata and Suzuki (2002; 2004) have employed measures of creative problem solving (i.e. association tasks) widely utilized in the field of cognitive psychology for examining executive attention in terms of cognitive flexibility (for review, see Ashby, Isen, & Turken, 1999). Finally, Kuo (2001), Kuo and Sullivan (2001), and Faber-Taylor and colleagues (2002) have utilized the Backwards Digit Span Task, a working memory task, as a measure of attention.

Since, in cognitive psychology, a relationship has been found to exist between controlled attention and working memory, we can also ask whether or not a relationship exists between ART and working memory. If directed attention is a type of controlled, voluntary attention, and performance on working memory tasks is influenced by a limited attentional capacity, then perhaps restoration of directed attention also impacts performance on working memory tasks. Research in the plant-human interaction literature has used a wide variety of working memory tasks to assess directed attention, but the results of nature's influence on such tasks have been mixed. On some types of working memory tasks, performance is positively influenced (Faber-Taylor et al., 2002; Kuo, 2001; Kuo & Sullivan, 2001; Tennessen & Cimprich, 1995) and on others, it is not (Hartig et al., 2003; Tennessen & Cimprich, 1995; Tooley et al., 2006).

PLANT-HUMAN INTERACTION RESEARCH FINDINGS

Effects on Attention

Observations of the positive effects of nature and plants on attention are numerous and remarkable; it is a strength of the literature that so many types of exposure to nature seem to enhance one's ability to direct attention. The challenge, however, lies in the interpretation of the varied methodologies and dependent variables employed by researchers in the measurement of directed attention. For example, Tennessen and Cimprich (1995) used three tasks and a questionnaire to assess whether the degree of naturalness in a dorm window view was associated with greater directed attention: the Necker Cube Pattern Control Test (NCPT), the Symbol Digits Modalities Test (SDMT), the Backwards Digit Span Task (BDS), and an Attentional Function Index (AFI) questionnaire. Students with 'all natural views' scored significantly higher on the NCPT than students with either 'mostly natural', 'mostly built', or 'all built' views. When the researchers collapsed the data from the latter three view types into one score, they found that the 'all natural' group also performed significantly better on the SDMT and the AFI. However, when they collapsed the data into the two natural vs. the two built views, they found differences only in the NCPT (see Figure 2) and SDMT. What is interesting in this study is cognitive psychologists do not employ the NCPT, SDMT, or the AFI as tasks for assessing voluntary attention, and only use the Backwards Digit Span task (which was unaffected by the window view in this study) for measuring working memory. Therefore, it is difficult to interpret what attention process (i.e. selective, sustained, or executive) was actually being employed during the other two tasks since the NCPT and SDMT are not validated measures of a specific attention process, although they appear to measure attention. So, although nature was observed to positively influence performance on tasks relying on some form of attention, from this study it is not possible to know which of the processes were influenced.

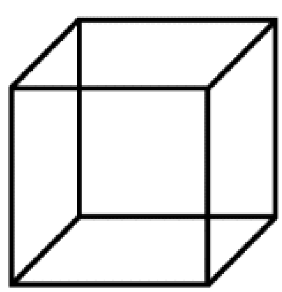

Figure 2. The Necker Cube Pattern Control Test

Similarly, Hartig, Mang, and Evans (1991) reported two pre-post studies where proofreading was used as a test of nature's attention-restoring effects. In the first study, three groups were compared: 1) wilderness vacationers, 2) urban vacationers, and 3) those with no vacation. A comparison of groups found that only wilderness vacationers showed significant improvement in proofreading performance, a task requiring a high degree of concentration. In a second study by the same researchers, after 40 minutes of tasks assumed to induce attentional fatigue, participants were given a break period consisting of a nature walk, a walk around town, or passive relaxation sitting indoors. Then they were given a proofreading test. Those who had taken the nature walk scored the highest. Once again, it appears nature has a positive influence on the restoration of attention, but we are left wondering what network of attention is being influenced, or if the influence relates to the inhibitory executive processes that S. Kaplan (1995) states are required for directed attention. Proofreading relies on selective attention to visually search for mistakes, and sustained attention to maintain a vigilant search, yet it has not been validated as a measure of either attention process, as defined by conventional cognitive psychology.

Comparatively, a few studies have employed working memory tasks as measures for assessing directed attention capacity. A longitudinal field study by Hartig and colleagues (2003) did not find differences in directed attention capacity for participants on a nature walk versus those on an urban walk, as measured by a working memory continuous performance task. In this study, the researchers also employed the Necker Cube as a measure of directed attention, and measured participants prior to and after a walk in either a nature reserve or an urban area. However, unlike the findings of Tennessen and Cimprich (1995) whereby natural window views enhanced performance on the Necker Cube, no differences were observed between nature and urban settings in the pre- to post-walk. Since there are many differences between this study and the Tennessen and Cimprich (1995) study, it is difficult to determine why differences were not observed between the nature and urban conditions, especially since in this study, participants were immersed in the environment and not simply viewing it from a window.

As mentioned earlier, working memory tasks have also been employed as measures of attention. The following two studies utilized the same working memory task, and found similar positive results. Kuo (2001) used the Backwards Digit Span task to assess attentional fatigue in residents living in matched high rise housing in Chicago. She found that residents who had trees and green spaces outside their apartments showed better performance on the task than residents surrounded by barren, treeless areas. She also found that residents' ability to manage life stress was directly related to performance on the task, and therefore related to the amount of green space availability. Similarly, Kuo and Sullivan (2001) examined the effects of inner city green space on aggression and mental fatigue in residents living in the same matched high rise apartments. Findings indicated that residents living in apartments with surrounding green space and trees performed better on the same task and indicated less aggression than those residing in apartments with no nearby green space or trees. The researchers also found that better mental ability as assessed by the task was directly related to less aggression. As controlled attention and executive processing are required to perform well on a working memory task, these two studies show consistent results of nature's positive influence.

A third study has also explored mental fatigue in the inner city, but addressed the concern in children. Faber-Taylor, Kuo, and Sullivan (2002) examined the influence of nearby nature on the self-discipline of 7-14 year old city children living in matched high-rise apartment housing. The researchers administered a series of tasks designed to measure three areas of self-discipline (concentration, inhibition, and delay of gratification), then standardized the scores of the tasks to create one representative score characterizing the overall area of self-discipline being assessed. For example, a summary score for concentration was based on a standardized score of the following tasks: Necker Cube Pattern Test, Symbol Digits Modalities Test, Alphabet Backwards, and Backwards Digit Span Task. The researchers found that girls who lived with greener views from home showed greater concentration, exhibited less impulsive behavior, and were more able to postpone gratification than girls who had less green space. However, the effect was not significant in any category for boys. However, this was not surprising to the researchers when they considered that boys often have a larger home territory to explore, and that this area might include more natural surroundings. What is most challenging about this study, from a cognitive science standpoint, is that we are unable to assess whether or not nearby nature affected each task individually. It could be that one task score pulled the data towards significance, but the other tasks were not significant across the conditions. Also, since not all the tasks utilized are standard measures of attention as employed in cognitive research on attention, we cannot determine what network of attention is actually being affected by exposure to nature.

Using survey techniques, these same researchers (Faber-Taylor, Kuo, & Sullivan, 2001) also found that children with Attention Deficit Hyperactivity Disorder (ADHD) were able to better concentrate, complete tasks, and follow directions after playing in “green” settings, such as when fishing or playing soccer, than children who played in a “not-green” setting, such as when playing video games or watching television. Results also indicated that the “greener” a child’s play area, the less severe his or her attention-deficit symptoms. A more recent national survey study on the same subject (Kuo & Faber-Taylor, 2004) also found that children who engaged in activities in greener settings had reduced ADHD symptoms. As the surveys were based on reports from the parents of the children suffering from ADHD, there was a possibility for bias, and the researchers noted this in their discussion, calling for additional research using more objective performance measures of attention deficits.

Two studies have found evidence that green space and nearby nature also have a positive impact on cognitive performance and stress in more rural settings. For example, Wells (2000) found that children who moved to a home with more access to nature settings exhibited higher levels of cognitive functioning after the move than children who experienced less increase in nearby nature after a move. However, the sample size was very small, and the child's cognitive functioning was assessed by the parents using a survey instrument designed to measure Attention Deficit/Hyperactivity Disorder. Therefore, the study does not provide insight into the specific process of attention affected by nearby nature. In a second study, Wells and Evans (2003) examined nature as a buffer of life stress in children living in rural settings. They found that levels of nearby nature, as recorded by a 'naturalness scale' moderated the impact of stressful life events on the psychological well-being of children. Specifically, the impact of life stress was lower among children with high levels of nearby nature than among those with little nearby nature.

Effects on Creativity

The influence of nature and plants on creative task performance is a relatively recent advancement in the literature, with no focus on a specific theory. Two studies were based on the hypothesis suggesting window views in general enhance performance on creative tasks but not on productivity tasks requiring more concentration (see Stone & Irvine, 1994). Additionally, a study by Larsen and colleagues (1998) found as the density of plants in an office setting increased, mood was more positive but task performance on a letter identification task (i.e. productivity task) decreased. The latter authors hypothesized that multiple sensory stimuli such as plants or window views of natural settings distract participants on tasks requiring concentration but enhance creativity. In a study designed to compare creative and non-creative task types, and based on the hypotheses of the previously cited studies, Shibata and Suzuki (2002) examined the effects of the presence of plants on a sorting task and a creative association task. Findings indicated that plant presence positively affected performance on the association task but not the sorting task, and for male subjects but not female subjects. A second study by Shibata and Suzuki (2004) found female participants, but not males, found more word associations when a plant was in the room, as opposed to a magazine rack or no embellishment. It is still relatively unclear from these two studies exactly how plants are influencing creative problem solving. In both cases, the positive results were based on interactions between self-reported satisfaction with the task and the task score itself. In addition, gender differences in the two studies call into question the consistency of the findings since both studies were extremely similar in terms of methodology, yet the results were not replicated.

Other studies assessing creativity have used a standardized instrument, the Abbreviated Torrance Test for Creative Thinking (Torrance & Goff, 2002), which measures the number of ideas generated (both figurally and verbally) as well as the originality, elaboration, and flexibility of those ideas. Ulrich (2004) examined how a combination of flora in an office environment affected creativity. Conditions included a workplace with flowers and plants, sculpture inspired by natural forms, or an unembellished condition. When flowers and plants were present, females generated more creative, flexible solutions and men generated 30% more ideas. A follow-up study by Tooley et al. (2006) replicated Ulrich's work with slight modifications. The researchers removed the sculpture condition, and instead teased apart the flower and plant condition, creating four conditions: 1) plants only, 2) flowers only, 3) plants and flowers, and 4) no embellishment (control). Findings indicated that creative flexibility was significantly higher for all three plant/flower conditions compared to the control, with no significant differences between the plant, flower, or plant/flower conditions. The researchers also found the presence of flowers reduced physiological stress (as measured by reductions in blood pressure and heart rate) and increased satisfaction with life more than any other condition. However, the flower condition impaired performance of non-creative cognitive tasks that utilized working memory and reasoning.

Based on the concept of creativity proposed by Torrance, a second series of studies was conducted to elucidate the relationship between the physical work environment and creativity. McCoy and Evans' (2002) first study found when individuals were asked to sort pictures of physical characteristics of interior environments which they themselves perceived would be most potentially creative, they rated environments containing natural scenes, views of nature in the window, and rooms containing natural materials such as stone and wood walls as preferred most as creative environments. The second study was designed to assess whether the actual environment would be conducive to creative task performance. Using the full version of the Torrance Test for Creative Thinking (TTCT) which included a creative collage activity, participants were placed in one of two areas, one which was rated for high creative potential and contained living plants and flowers as well as natural building materials. The other setting contained no plants or natural building materials and was rated as having low creative potential. The authors found that only the collage was affected by the environment. Participants were significantly more creative when plants and natural materials were present.

Effects on Positive Emotions

Studies frequently examine mood alongside other dependent variables, and, almost always, it is measured using self-report rating scales such as the Profile of Mood States (POMS: Schachem, 1983), Positive and Negative Affectivity Scale (PANAS: Watson,Clark, & Tellegen, 1988), or the Zuckerman Inventory of Personal Reactions (ZIPERS: Zuckerman, 1977). An examination of the literature shows that findings seem at least partially to depend on the chosen self-report mood measure. Most research founded in Psycho-Evolutionary Theory has used the Zuckerman Inventory of Personal Emotional Reactions (ZIPERS), and has observed differences in mood state between natural and urban conditions (Hartig et al., 1991; Hartig et al., 2003; Hartig et al., 2006; Ulrich & Simons, 1986; Ulrich et al., 1991), but research conducted using other subjective measures of mood, such as the Profile of Mood States, has not observed differences between treatment conditions (Kuo & Sullivan, 2001; Tennessen & Cimprich, 1995; Tooley et al., 2006). Unfortunately, Tennessen and Cimprich (1995) only reported findings from the depression-dejection sub-scale of the POMS mood measure, making it impossible to know if the natural environment affected other facets of mood. Interestingly, a recent study by Hartig and colleagues (2006) utilized both the ZIPERS and the Positive and Negative Affectivity Scale (PANAS) to determine whether the ZIPERS was an accurate measure of positive and negative affect. The researchers found similar differences in positive affect for both scales, with reports of significantly higher scores after viewing nature but not urban pictures.

Attention Restoration Theory does not make any specific hypotheses about the impact of nature and plants on mood state. However, Psycho-Evolutionary Theory states that after a stressful situation, exposure to plants and natural settings improves positive mood and reduces negative mood. Studies based in this theory have reported these changes when participants are exposed to natural settings as opposed to urban settings (Hartig et al., 2003; Ulrich, 1979; Ulrich et al., 1991). Findings also indicate that physiological stress, or arousal (as measured by heart rate, blood pressure, and/or skin conductance), is lower after viewing exposure to plants and nature as compared to urban settings (Chang & Chen, 2005; Hartig et al., 2003; Laumann, Gärling, & Stormack, 2003; Ulrich & Simons, 1986; Ulrich et al., 1991) or to no flora (Lohr, Pearson-Mims, & Goodwin, 1996). For example, Chang and Chen (2005) found that a combination of window view of nature and indoor plants produced the most positive responses to dependent measures of stress and mood. In this study, they measured participants' reactions to one of six types of slides of an office room, with a window with a view of the city, a window with a view of a city and indoor plants, a window with a view of nature/trees, a window with a view of nature and indoor plants, no window view, or no window view but indoor plants. Dependent measures were responses on an electroencephalogram (EEG), electromyography (EMG – facial muscle tension), blood volume pulse (BVP), and a state-anxiety questionnaire. The authors concluded that window views resulted in more positive effects in the workplace than indoor plants, and views of nature from the window have more beneficial effects than city views.

Cognitive psychological research indicates that changes in mood state often affect cognitive processes. However, since most of the above studies reflect empirical work supporting Psycho-Evolutionary Theory, very few of them measure attention (Hartig et al., 2003; Laumann et al., 2003) or working memory (Hartig et al., 2003). In the few integrative studies that do, attention and working memory performance did not differ between urban and natural environments. A study unrelated to the theory did find that, in an office environment, mood was enhanced as plant density increased, but performance on a productivity task decreased (Larsen et al., 1998). However, it is important to note the productivity task was not necessarily a measure of attention, simply a measure of performance. In the current literature, researchers have yet to examine whether or not mood state mediates the effects of nature and plant exposure on cognition.

As research supporting the Psycho-Evolutionary Theory often places participants under stress before exposing them to natural (or urban) settings, it is possible the induced stress is powerful enough to alter mood state, and thus, when exposed to nature, participants were more likely to feel the effects of the exposure. However, recent work has found affective responses to nature and urban pictures are not only rapid, they can occur without any pre-stressor condition. In the first study, Korpela, Klemettilä, and Hietanen (2002) primed participants by presenting them with both pre-rated highly restorative nature pictures and urban stimuli of low restorativeness. Each picture was followed by vocal presentations of a word spoken with joy, anger, or no emotion. After each word, participants were asked to judge whether the word expressed joy or anger. Findings indicated the reaction times to vocal expressions of anger were faster after urban pictures than nature pictures. The reverse was observed for vocal expressions of joy – participants responded faster after nature pictures than urban stimuli. However, because this study did not use a neutral stimuli condition, the researchers were unable to determine if only one stimulus (natural or urban) was responsible for the affective response. Therefore, in a follow-up study, Hietanen and Korpela (2004) added a neutral stimulus condition of pictures rated as having medium restorativeness, and controlled all pictures for their level of complexity and color (using grayscale pictures only). In addition, the researchers used facial expressions of anger and happiness in order to attempt to generalize to other types of emotional stimuli. Findings indicated results similar to those of the previous study, however, when compared to the pictures of medium restorativeness, it was found that only negative scenes of low restorativeness (urban scenes) facilitated responses to angry facial expressions. Reaction times to happy faces were not faster after positive environment stimuli such as pictures of nature. Taken together, the two studies lend support to the idea that rapid affective responses occur only for negative stimuli, a concept in keeping with literature presented earlier on the relationships between emotion and cognition. For example, categorical negativity theory (Pratto & John, 1991) and the evolutionary threat hypothesis argue that enhancing attentional awareness would be beneficial for survival as automatic evaluation of negative stimuli it would allow an organism to respond more quickly to threat (see Shimmack, 2005).

PURPOSES OF THIS RESEARCH

It is apparent from the cognitive psychology literature the human brain is an integrated and complicated organ which can be influenced by the external environment or emotional states. These influences can either benefit or degrade cognitive performance, at least in the realm of attention, creative problem solving, and working memory. What is less apparent is how exposure to nature and plants influences specific underlying cognitive processes. From the literature, it is not always clear which processes of attention are being influenced by exposure to nature and/or plants, or whether performance due to exposure to nature is being mediated by mood state. For example, perhaps exposure to natural stimuli makes individuals feel happier and more content, and this feeling is responsible for the enhanced performance on subsequent cognitive tasks.

It is clear that existing studies provide support for both theories and the literature contains a great deal of evidence to support the restorative effects of nature and plants on attention, stress, and mood. However, researchers who conduct studies in support of the two theories often do not use identical dependent measures, making comparisons difficult and definitive statements challenging. In addition, it is only recently that researchers have begun employing measures widely used in the cognitive sciences for measuring the selective, sustained, and executive attention processes.

Therefore, the main objective of the following series of studies was to explore the influence of natural stimuli on mood and cognition from a cognitive science perspective, utilizing dependent measures employed in that field for measuring the underlying processes of working memory, inhibition, sustained attention, and creative problem solving. In some cases, measures of working memory and attention used during this research were identical to those utilized in previous studies (i.e. Backwards Digit Span, Stroop Task). In other cases, measures were newly employed in the search for if and how nature and plants influence cognition. All of the cognitive measures administered during this research have been used in cognitive psychology for measuring sustained attention, and executive attention processes associated with inhibition, creative problem solving, and working memory.

In addition, since previous research has assessed effects on mood state as well as cognition, and cognitive psychologists have found relationships between mood state and cognitive performance, our second objective was to examine whether or not mood or affective state were influenced by exposure to natural stimuli. In order to be consistent with past literature, the self-report measures of mood used are identical to those utilized in previous studies.

Finally, as only one study thus far has compared different types of natural stimuli exposure to one another (potted plants and window views of nature: Chang & Chen, 2005), our third objective was to conduct a portion of these studies to assess possible differences between specific types of natural stimuli. Since many studies have used surrogates of nature, such as pictures and videos of natural settings as their form of stimuli, we chose to focus on the comparison of the viewing of pictures of plants versus a direct interaction with living plants.

CHAPTER 3

RESEARCH STUDIES

STUDY ONE: INFLUENCE OF WINDOW VIEWS AND VIEW CONTENT ON MOOD AND ATTENTION PROCESSES

The purpose of this study was to examine the effects of indirect access to nature on mood and cognition. We asked participants to sit in front of a large picture window where either (1) the shade was pulled down to block the view, (2) they had a view of a forest, or (3) the view was of buildings. After sitting for one minute, the participants were asked to fill out a self-report measure of mood, followed by one of two computerized attention tasks (sustained attention or inhibition) requiring a high degree of concentration. After completing this task, the participant spent ten minutes working on a creative problem solving task.

Based on reported findings that only performance on creative tasks, as opposed to tasks requiring a high degree of concentration, benefits from having access to general window views (Stone & Irvine, 1993; 1994) and studies which found exposure to flora enhanced creative task performance (Mitchell & Evans, 2002; Shibata & Suzuki, 2002; 2004; Tooley et al., 2006; Ulrich, 2004), my first hypothesis was that performance on the creative problem solving task would be enhanced by the presence of a window view, with the greatest performance in the nature group, as compared to the building view group, or not having a view.

Second, derived from research which observed that exposure to plants as compared to urban stimuli has enhanced mood state (Honeyman, 1987; Ulrich, 1979; 1981), we hypothesized that participants with a window view of nature would record more positive mood compared to those with a view of buildings or no view.

Finally, some studies have indicated that a window view might reduce performance on tasks requiring a high degree of concentration (Stone & Irvine, 1993; 1994) and plants may distract participants from tasks requiring this type of strict focus (i.e. productivity tasks; Larsen et al., 1998). However, one study has indicated that performance on attention tasks is positively influenced specifically by a window view of nature (Tennessen & Cimprich, 1995). Therefore, we did not make any specific predictions about the influence of the window view on the two attention tasks.

METHODS

Participants

Undergraduate students (N = 145) from the Horticulture and Psychology departments of a major university participated in the study for course extra credit. The gender breakdown was 24 males (16.5%) and 121 females (83.5%). Participants were randomly assigned to one of three conditions: a window view of a forest (N = 48), a window view of buildings (N = 49), or a control consisting of the same windows with the shade pulled down (N = 48).

Constructs and Measures

Independent Measure

Window View. Participants were randomly assigned to sit at a desk which directly faced a picture window where a) either the shade was pulled down (control) so no view was visible, or with a view of either a b) forested area or c) buildings (see Illustrations 1 and 2).

Illustration 1. Window View of Nature

Illustration 2. Window View of Buildings

Dependent Measures

Mood. The Short Form of the Profile of Mood States (POMS-SF; Shacham, 1983) is a questionnaire which includes six factors (anxiety/tension, depression/dejection, anger/hostility, fatigue/inertia, vigor/activity, and confusion/bewilderment). Participants were asked to answer as honestly as possible, and to rate their feelings at the moment.

Attention. Two attention tasks (sustained and executive control) were administered on a Palm Pilot, using a program called MiniCog (Shepard & Kosslyn, 2005), a software package developed at Harvard University.

The vigilance task is a measure of sustained attention, or the ability to concentrate and react to a specific stimulus for a sustained period of time. Small geometric shapes are presented one at a time on the screen. The set of shapes contains one target (a particular parallelogram) and four distractors. Because targets are presented occasionally and randomly, the test-taker must maintain concentration to detect them (see Manly, Robertson, Galloway & Hawkings, 1999). Scoring is based on reaction time and the percentage of errors.

The Stroop task (Stroop, 1935) is a well-known measure of inhibition, or executive control. In this task, participants see color names on the screen, one at a time. Participants are required to press the labeled button corresponding to the color of the 'ink' while ignoring the meaning of the word (e.g., the word "brown" might be printed in blue ink). Scoring is based on the amount of interference (reaction time) and percent error recorded for the task.

Creativity. Items were chosen from the Remote Associates Task (RAT; Bowden & Jung-Beeman, 2003). For our purposes, we chose 21 items of three levels of difficulty, and created a 3 page booklet containing seven items per page. (See Appendix A for complete test). Each item consisted of three words followed by a blank space. Instructions were to provide, in the space, a word that related to each of the three words given in the item. For example, a moderately difficult item was:

MOWER ATOMIC FOREIGN ______________.

(The correct answer to this item is POWER).

Procedure

After seating the participant, the researcher explained the tasks to be administered in the study, asked for any questions, and provided an informed consent form followed by a demographics questionnaire. After the consent form and demographics sheet were collected, participants were asked to sit and relax while the tasks were prepared. This gave them a chance to look at the view (or shade in control).

After approximately one minute, the researcher returned and administered the self-report mood measure. During this time, participants were randomly assigned to receive either the Stroop task (executive attention – inhibition) or the Vigilance task (sustained attention), each of which lasted approximately two minutes. The researcher administered the task following completion of the mood questionnaire. Participants were asked to alert the researcher once the task was completed. Immediately following this task, the researcher gave participants a booklet containing twenty-one items of word associates of the Remote Associates Test (creative problem solving task). The directions advised that participants had ten minutes to complete the task, and to spend no more than thirty seconds on any one item, as additional time was not likely to produce an answer. After completion, participants were asked if they had any questions, and if not, were free to leave.

RESULTS

View or No View: Effects on Creative Problem Solving

Our main prediction was that creative problem solving would be positively affected by a window view, with natural views enhancing performance more than building views, as compared to the control. First, based on Stone and Irvine's (1994) prediction that a view would positively contribute to enhanced creativity, we constructed a one-way ANOVA with gender as a covariate, collapsing across the two view content types (natural and built) and examined the effects of a window view on creative problem solving. In accordance with Hypothesis One, participants with a window view (M = 8.61, sd = .393) correctly answered significantly more items on the creative problem solving task than the control group with no view (M = 7.02, sd =.496), $F_{(2,129)} = 8.61$, $p = .004$. See Figure 3.

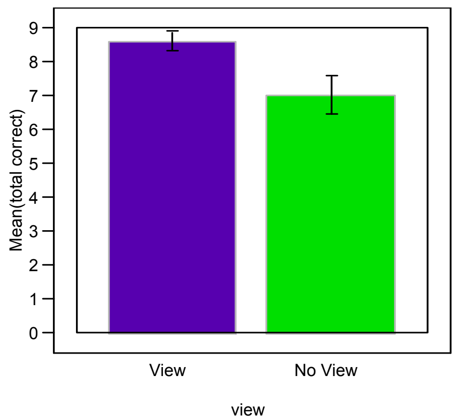

Figure 3. Mean Number of Correct Responses on Creative Task by View

View Content - Natural, Buildings, or No View: Effects on Creative Problem Solving

When we separated view content into natural versus building views, we also found partial support for our hypothesis. Using a one-way ANOVA with gender as a covariate, we found that a trend emerged in relation to the content of view. Table 1 shows that participants with a window view of nature did significantly better on the task than those having no view, with those viewing an urban setting falling somewhere in the middle, $F_{(2,127)} = 5.12$, $p = .0073$. A post-hoc LSD indicated that participants with either a natural or a building view did significantly better than the control, but scores for participants with either view content did not significantly differ from one another.

Table 1. View content by Mean Number of Items Correct on Creative Task

	View Content			*F*	p *value*
	None	*Natural*	*Building*		
Mean # Correct Items (sd)	7.02 (.496)	9.00 (.541)	8.27 (.465)	5.19	.0073

View and View Content: Effects on Difficulty Levels of Creative Problem Solving Task

Employing a one-way ANOVA with gender as a covariate, we also examined performance on the creative problem solving task by item difficulty, of which seven items were represented by the following levels: easy, moderate, and difficult (moderate items were identical to those used by Estrada, Isen, & Young, 1994; easy and difficult taken from Bowden & Jung-Beeman, 2003). On the easy items, those with a view did significantly better than those with no view, $F_{(1,128)} = 7.05$, $p = .0089$. View content followed the same trend as above $F_{(2,127)} = 4.69$, $p = .01$. Post-hoc LSD analysis indicated that participants with a natural view did significantly better on the task than the control group, but those with a building view did not differ significantly from either the control or the natural view group. View affected performance on moderately difficult items the same way, with view contributing significantly to better performance on the task, $F_{(1,129)} = 6.44$, $p = .012$. Content of the view also mattered, $F_{(2,128)} = 3.94$, $p = .022$, with the natural view enhancing performance significantly more than the control (having no view) but with no significant difference between the building view and either the natural view or the control. On the extremely difficult items, however, there was no difference between the content of the view, or whether one had a view. Table 2 provides the means and standard deviations for each type of item across the three conditions.

Table 2. View Content by Mean Number Correct on Item Difficulty of Creative Task

Item Difficulty	*Mean Number Correct (sd)*			*F*	p
	No View	*Natural View*	*Building View*		*value*
easy items	1.81 (.244)	2.78 (.267)	2.31 (.229)	4.69	.01
moderate items	4.21 (.273)	5.17 (.298)	4.79 (.256)	3.94	.022
difficult items	1.00 (.091)	1.05 (.099)	1.17 (.085)	1.06	.35

Effects on Positive Mood

Second, we hypothesized more positive mood in participants with a natural view as compared to those with a built view. For the examination of whether mood state was affected by the view or its content, we conducted a one-way ANOVA with gender as a covariate, and found the view did not affect the overall mood of participants. However, the fatigue-inertia subscale of the POMS mood measure was affected by the view content. Participants reported more fatigue and inertia feelings if they had a view of nature (M = 2.47, SD =.144) versus a view of buildings (M = 1.97, SD =.132), $F_{(2,129)} = 4.57$, p = .012, but neither content differed significantly from the control group (M = 2.34, SD =.133).

Since it was possible that dispositional mood state might affect subsequent task performance, we also designed a linear model using the mood subscale variables as predictors. We found mood state did not significantly predict performance on either the creative problem solving or attention tasks.

Effects on Sustained Attention and Executive Control

We did not make any prediction regarding the effect of a window view or its content on attention tasks requiring a high degree of concentration. Interestingly, a one-way ANOVA with gender as a covariate indicated no difference between view and control, or view content, emerged for the sustained attention task. The only marginally significant effect found was]for the percentage of errors made on the executive control, or Stroop task, $F_{(2,129)} = 2.61$, p = .08. A post-hoc LSD analysis indicated that participants with a view of buildings (*M* = 3.53, *SD* =.937) made significantly more errors than those with a view of nature (*M* = 1.05, *SD* =.976). However, neither group differed significantly from the control (*M* = 1.43, *SD* =.950).

DISCUSSION

In accordance with previous research (Stone & Irvine, 1994), the findings of this study established that access to a window view does positively impact one's performance on creative problem solving tasks. However, unlike the study by Tennessen and Cimprich (1995), in which the authors observed participants living in a dormitory with a window view of nature, versus those residing with a view of buildings, showed better performance on tasks assumed to measure directed attention, our study did not find that performance on attention tasks was significantly influenced by window views or their content. This brings up an important unanswered question: was an exposure to nature of ten minutes duration long enough to influence performance or do individuals need a longer exposure time, such as an entire semester of a view from a dorm window? We did observe differences in a creative problem solving task which relies on executive attention processes, but participants had ten minutes to work on the task and look out the window while pondering answers. Also, the study by Tennessen & Cimprich (1995) was based on students living in a dormitory, presumably having a specific window view for the entire semester. Perhaps the few minutes of exposure to nature views were not enough to influence attention tasks requiring a high degree of concentration. Therefore, we attempted to answer this question by examining effects on attention tasks with an exposure time equivalent to the creative problem solving task (i.e. ten minutes). Additional study findings concerning the beneficial effects of nature on attention tasks are based on direct exposure, such as nearby green space and trees (Kuo & Sullivan, 2001; Wells, 2000) or walks in natural areas (Hartig et al., 1991), we also examined a more direct type of exposure to nature in the additional studies.

STUDY TWO: EFFECTS OF EXPOSURE TO PLANTS ON WORKING MEMORY AND SUBJECTIVE WELL-BEING

In the second study, we examined the effects of more direct access and a longer exposure time to nature on cognition and well-being. We conducted an experiment in which participants were placed in two identical rooms, except half the participants viewed plants on a shelf in the room while the other half viewed other types of office embellishments such as sculpture on an identical shelf. We asked participants to relax for *ten* minutes (the same amount of time those in the previous study had for the creative problem solving task), and gave them three magazines to choose from should they wish to read. The three magazines, *Us, Consumer Reports, and Sports Illustrated,* contained no pictures of plants or office embellishments. After the ten minute period elapsed, participants answered a series of subjective well-being questionnaires designed to assess mood, optimism, mindfulness, physical health, and satisfaction with life. We then administered a working memory task, the Backwards Digit Span Task, to determine whether the task would also be influenced by the different room embellishments.

Our first hypothesis was participants who had plants in the room would record more positive mood, satisfaction with life, and optimism than those with other office embellishments. We based our first prediction on previous research which has also used self-report measures and has observed that people who are exposed to plants or natural stimuli in an office report fewer physical ailments (Fjeld, 2000; Fjeld &

Bonnevie, 2002), more satisfaction with their jobs (Kaplan, 2001), and more positive mood (Kaplan, 2001; Larsen et al., 1998).

Since previous research has observed that natural areas, in comparison to areas lacking in nature, have a positive influence on the Backwards Digit Span Task but not necessarily devoid of visual stimuli (Kuo, 2001; Kuo & Sullivan, 2001), we also predicted participants in the plants in the room condition would perform better on the working memory task than those in a room with other types of office embellishments.

METHODS

Participants

Participants were 36 undergraduate students (21 women, 15 men), between the ages of 18 and 21 years, enrolled in introductory psychology courses at a major college in upstate NY. Participants were randomly assigned to one of two conditions: a room with plants (N = 18) or a room with other types of office embellishments (N = 18). Participants earned extra credit toward their course grade for participation in the experiment.

Constructs and Measures

Independent Measure

Exposure to Plants. The independent variable of interest was the presence of plants in a study room. The difference between the study rooms in which participants completed the dependent measures was the presence of green plants or other types of office embellishments. Six varieties of green plants (aloe, bamboo, two non-flowering orchids, red colia, and oregano) were placed on the shelves in the experimental room. In the control room, six objects (glass apple, small clay vase, wooden carved figurine, two metal picture trees, and a pleasantly-shaped metal pen holder) were placed on the shelves.

Dependent Measures

Working Memory. The Backwards Digit Span Task (BDS) is designed to test working memory by providing subjects with a sequence of three to seven numbers for which they must repeat the sequence backwards in the correct order. Participants in this experiment were given these sequences in sets of 3's; for example, three sets of four numbers (3 5 2 9, 7 9 1 8, 5 8 3 2), three sets of five numbers, and so forth up to seven numbers. Scoring is determined by whether the participant correctly repeats backwards at least two out of three sequences in a set. For example, if they correctly repeat back two number sequences backwards consisting of four numbers each, they score a four. The highest level at which they correctly repeat at least two number sequences in a set is their final score.

The following is the list of the dependent measures of the subjective well-being construct completed by all participants using an online computer questionnaire:

Positive and negative affectivity. The Positive and Negative Affect Schedule (PANAS; Watson, Clark & Tellegen, 1988) is a scale consisting of 20 items, each responded to on a 5-point Likert scale (1 = *very slightly or not at all*; 5 = *extremely*). Negative affectivity is positively related to symptom self-reports (Watson & Pennebaker, 1989) and was controlled for statistically in those measures.

Mood states. The Short Form of the Profile of Mood States (POMS-SF; Shacham, 1983) is a questionnaire which includes six factors (anxiety/tension, depression/dejection, anger/hostility, fatigue/inertia, vigor/activity, and confusion/bewilderment). The 37-item POMS-SF has subscale internal consistency estimates quite comparable to those for the original, 65-item scale (POMS; McNair, Lorr, & Droppelman, 1971), and the total and subscale POMS-SF and POMS correlate at .95 or better (Curran, Andrykowski & Studts, 1995).

Dispositional mindfulness. The Mindful Attention Awareness Scale (MAAS; Brown & Ryan, 2003) is a measure of dispositional mindfulness, or awareness and attention to internal and external stimuli.

Life satisfaction. Life satisfaction, a component of subjective well-being, was assessed with the Temporal Satisfaction With Life Scale (TSWLS; Pavot, Diener & Suh, 1998). TSWLS measures satisfaction with one's past, present, and anticipated future life. It consists of 15 items, each responded to on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree).

Optimism. Optimism, another component of subjective well-being, was assessed with the Revised Life Orientation Test (LOT-R, Scheier, Carver, & Bridges, 1994; cf. Scheier & Carver, 1985). The scale contains six items including, "In uncertain times, I expect the best," plus four filler items. The items are rated on a 5-point Likert scale (1 = *strongly disagree*; 5 = *strongly agree*).

Physical well-being. We assessed physical well-being with the Pennebaker Inventory of Limbic Languidness (PILL; Pennebaker, 1982), on which participants indicate which of 54 symptoms and complaints they have experienced over a period of time.

Procedure

The experiment was performed in two identical study rooms each reached through a separate door from a larger meeting room. Both study rooms contained one rolling chair and a desk running the length of one wall. On the desk was a computer, three innocuous, non-plant related magazines (*Sports Illustrated, Us, and Consumer Reports*), and a two-tiered, white shelf that stood in the corner of the desk. The doors to the study rooms were kept closed between time slots so that when participants entered the larger meeting room, they were unable to see into the study rooms.

Upon entering, participants were greeted and thanked for their willingness to participate in the experiment. Participants were given a consent form and asked to read, sign, and return it to the experimenter. During this time, participants were randomly assigned to condition by the experimenter. After signing and returning the form, participants completed a demographic questionnaire.

Once the two forms were completed, participants were informed the experiment would take no more than 45 minutes and consists of a relaxation period and two tasks. The experimenter then described the experiment as follows:

"I will place you in one of the study rooms behind you. For the first ten minutes, the only thing I would like you to do is just sit and relax. This is so that you will be at a baseline when you begin the tasks. There are a few magazines in the room which you are welcome to read, but other than that, please just sit and relax. After 10 minutes, I will knock on the door, enter, and turn on the computer monitor. The first task requires you to fill out a series of questionnaires on the computer. There are about 125 questions. The task should take no more than 15 minutes. Please take your time and answer the questions to the best of your ability. If at any time during the experiment you have questions, please quietly open the door and let me know. This way, you will not disturb the participant in the other room." (This sentence was omitted if only one participant was present). "When you are finished with the task, please crack open the door to indicate you are done. I will then give you the second task, which will be on the Walkman and tape recorder (points to items on meeting table). You will listen to directions on the Walkman and record your answers out loud into the tape recorder. When you have completed this task, you are finished."

After participants indicated they understood and had no questions, the experimenter led them into one of the study rooms, and closed the door behind them. The experimenter, using a timer, waited in the meeting room for ten minutes. When the time period had elapsed, the experimenter knocked on the study room door, entered the room, and turned on the computer monitor. Participants were shown at the top of the online questionnaire where they should insert their subject number, and the experimenter reiterated the fact that participants should take their time and answer the questions to the best of their ability. Participants were instructed upon finishing the online questionnaire they should hit the submit button at the bottom of the screen but not log out of the computer. When they were done, they were told to crack open the door so that the experimenter would know that they were finished and could bring in the tape recorder task.

Once the participant opened the door, the experimenter came into the study room and set up the tape recorder on the table, and handed the participant the Walkman. Participants were instructed to hit play on the Walkman then immediately hit record/play on the tape recorder, listen to the directions, and record their answers in a normal voice into the recorder. The experimenter turned off the computer monitor, closed the door, and waited for the participant to complete the second task, which was a Backwards Digit Span cognitive test. When finished, participants could exit the study room. They were thanked again for their participation and informed that the results of the experiment would be emailed to them upon completion of the full study. They were also told that if they had any questions in the meantime, they should direct them to the professor on the copy of the consent form.

Follow-Up Questionnaire

After analyzing the data associated with the Online Questionnaire and the Backward Digit Span tasks, we decided to initiate a follow-up questionnaire through email correspondence with the participants. The email thanked all the participants for their help in the study and told them that after our initial analysis of the data, we found we had a few more questions we hoped they might answer so that we might better understand our results. Finally, we explained to the participants that once the data were fully analyzed, we would send them an email that explained the overall purpose of the study.

The email questionnaire consisted of the following three items:

1. Please describe everything you can remember about the study room in which you completed the two assigned tasks;
2. How did the study room make you feel?
3. Please tell us what the weather was like on the day you participated.

Participants were asked to complete the questions and submit them by email reply.

RESULTS

Our main focus was the hypothesis that the presence of plants in the study room, as opposed to other types of embellishments, during the tasks would manifest itself by a higher score on the Backwards Digit Span working memory task and more positive scores on the various subjective well-being scales. Therefore, we conducted a one-way ANOVA with gender as a covariate, in order to determine the effect of plants and objects on working memory and subjective well-being.

Impact on Working Memory

Contrary to our prediction plants would enhance performance on a working memory task, we did not observe any significant differences between our two conditions on the Backwards Digit Span Task, $F_{(1, 35)} = 2.43$, $p = ns$.

Impact on Subjective Well-Being

For four of the six online questionnaire scales, no main effects or interactions were discovered. However, we did find statistical significance for the two remaining scales, and our findings indicated a surprising result. We stated earlier in the Methods Section that for the PANAS (Positive and Negative Affect) Scale, Negative

Affectivity is positively related to symptom self-reports (Watson & Pennebaker, 1989). Indeed, this relationship was found in our experiment, but not for the group we anticipated. Participants in the plant group (M = 1.95, sd = .174) reported greater negative affect, $F_{(1, 35)} = 6.45$, $p = .016$ than participants in the object group (M = 1.33, sd = .176). In addition, more physical health symptoms, $F_{(1, 35)} = 3.70$, $p = .063$ were reported for plant group (M = 20.9, sd = 1.93) participants than for the object group (M = 15.8, sd = 1.95).

Follow-Up Questionnaire

Responses to the follow-up questionnaire were completed by 56% of participants (N=20). In describing the study room, only 45% (N=9) recalled either the plants (N=7) or objects (N=2) during the experiment. All participants who responded accurately remembered the weather on the day of their participation. Responses to 'how you felt while in the study room' varied greatly. None of the responses to the three questions elicited any statistical significance in relation to condition or tasks, nor did they affect statistical significance of other measures when used as covariates.

DISCUSSION

Although this study utilized a working memory task employed in previous research where exposure to green space and trees was found to have a positive effect on task performance (Kuo, 2001; Kuo & Sullivan, 2001), once again we are left with a question of the amount of time of exposure. In this study, we exposed participants to plants for ten minutes, the same amount of time the participants in the previous study had to work on a creative task. However, we saw no differences in performance on a working memory task, which requires a high level of attention and concentration. Indeed, it did not matter what type of embellishment was placed in the room. Perhaps a person requires a very long term exposure to nature, such as residing in a location containing natural areas, in order to observe benefits to working memory performance, and even ten minutes of relaxation in a room with plants is not enough to affect a task requiring a high degree of concentration and attention.

Another explanation for these results was the plants were not noticeably different, in terms of interest and/or complexity, from the sculpture/objects. The final possibility was exposure was not direct enough to strongly influence our participants. Therefore, in the two subsequent studies, we decided to explore the possibility that more direct interaction with plants might have a greater effect on cognitive performance and mood as opposed to simply viewing natural settings or plants.

STUDY 3A: EFFECTS OF ACTIVE VERSUS PASSIVE INTERACTION WITH PLANTS ON COGNITION AND MOOD

The purpose of this study was to examine the effects of total immersion and interaction with plants as compared to viewing pictures of plants. Since, in the previous study, we did not observe differences in cognition based on passive exposure to plants, and previous researchers have not examined the effects of working with plants on cognition and mood, we designed this study in such a way that some of our participants were actually touching and smelling plants in a conservatory for ten minutes (the same amount of exposure time as study two), some viewed pictures of the plants in a book while sitting in an office, and some acted as a control, with no passive or active plant interaction. In keeping with the ten minute exposure, participants then interacted with plants in either the conservatory or using the picture book. The control group had no plant interaction, and proceeded directly to the following tasks. Participants filled out a self-report mood measure, and completed a creativity test and a series of cognitive tasks.

We predicted participants interacting with living plants in comparison with those looking at pictures of plants in a book would show better performance on cognitive performance tasks involving attention and working memory and higher scores on a measure of creativity, and participants in both conditions would outperform the control group.

METHODS

Participants

Participants (N = 45) were recruited from introductory psychology courses at a college in central New York, with a gender breakdown of eight males and thirty-seven females. Participants were randomly assigned to one of three conditions: direct interaction with plants (N = 18), passive viewing of plant pictures in a book (N = 16), or a control who did not see any plants (N = 11). For their participation, students received extra credit in a psychology course. Participants were told the study was aimed at looking at relationships between the seasons and cognitive performance.

Constructs and Measures

Independent Measure

Type of Plant Exposure. A conservatory of plants was used for the plant-interaction condition. Participants completed a questionnaire which required them to find, touch, and smell living plants in one row of the conservatory only. See Illustration 3. A chair was provided so participants could sit to fill out the questionnaire. An unused office was used for the plant picture book condition. The room contained a desk, books on shelves, and a few chairs. See Illustration 4. No plants were present and a window shade was pulled to prevent bias from windowed views. The room was located a similar distance from the main researcher room as the conservatory. Participants were seated at the desk to complete a similar questionnaire using a plant taxonomy book called Flowering Plants of the World (1993). The book contains color drawings of plants and detailed descriptions. See Illustration 5. The control group did not proceed to any other location, but simply continued on with the dependent measures after filling out the perceived stress questionnaire. See Appendices B and C for the questions used for the two questionnaires.

Illustration 3. Photo of Conservatory Row for Plant Interaction Condition

Illustration 4. Photo of Office Setting for Book Condition

Illustration 5. Inside Photo of Plant Viewing Book

Dependent Measures

Perceived Stress. The Perceived Stress Scale (PSS) (Cohen, Kamarck & Mermelstein, 1983) is a widely used psychological instrument for measuring the perception of stress, or the degree to which situations in one's life are appraised as stressful. It is a 10-item self-report instrument with a five-point scale (0 = never, 1 = almost never, 2 =sometimes, 3 = fairly often, 4 = very often). The questions in the PSS ask about feelings and thoughts during the last month. The PSS scores are obtained by reversing the scores on the four positive items (items 4, 5, 7, and 8), and then summing across all 10 items.

Creativity. The Abbreviated Torrance Creativity Test for Adults (ATTA) (Torrance & Goff, 2002) is a shortened version of the Torrance Test of Creative Thinking (TTCT). The ATTA provides substantial insight into the creativity of adults by quantifying both figural and verbal creative strengths. It can be broken into subscales of fluency, flexibility, elaboration, and originality.

Positive and negative affectivity. The Positive and Negative Affect Schedule (PANAS) (Watson, Clark, & Tellegen, 1988) is used to assess positive and negative affect. The scale consists of 20 items, each responded to on a 5-point Likert scale (1 = very slightly or not at all; 5 = extremely). Participants were asked to rate the extent to which they felt this way during the previous four weeks.

Mood states. The Short Form of the Profile of Mood States (POMS-SF) (Schacham, 1983) includes six factors (anxiety/tension, depression/dejection, anger/hostility, fatigue/inertia, vigor/activity, and confusion/bewilderment). The 37-item POMS-SF has subscale internal consistency estimates quite comparable to those for the original, 65-item scale (POMS; McNair, Lorr, & Droppelman, 2003), and the total and subscale POMS-SF and POMS correlate at .95 or better (Curran, Andrykowski & Studts, 1995). Participants were asked to rate their feelings for the previous four weeks using the same instructions and scale as the PANAS.

Cognitive Performance. Cognitive performance was measured using a computer program called the Automated Neuropsychological Assessment Metrics (ANAM; Reeves et al., unpublished). The ANAM contains a battery of tests called the NeuroCognitive Screening Test Battery (NeuroCog), which assesses verbal and spatial working memory, sustained attention, mathematics, logistical reasoning, and motor control.

Setting

Participants met the researcher in a small private room. This room contained three smaller rooms, one of which was used by the researcher to go over procedures and administer self-report measure of perceived stress, and one (private room) was used by the participants to complete subjective well-being scales, cognitive tasks, and creativity test.

Procedure

The study took approximately forty-five minutes to complete. The participants met the researcher, filled out an extra credit form, and read and signed the consent form. The researcher explained the purpose of the study and asked for any questions. Participants were asked to fill out the Perceived Stress Scale. During this time, the researcher randomly assigned participants into treatment conditions, and placed participants in rooms corresponding to treatment condition. Participants who were brought to either the conservatory or the office were given directions and a questionnaire which required either direct interaction with plants in one row of the conservatory (plant condition) or perusal of plants in a plant taxonomy book (book condition) to find answers. Directions informed participants that they had ten minutes to complete the task, to stay seated, not rush, but to answer the questions to the best of their ability. If they finished early, they were told to relax and wait until the researcher returned. After a timed ten-minute period, the researcher returned and escorted the participant back to the private room and administered the POMS-SF and PANAS scales, followed by the creativity task and cognitive tasks. The control group was given the dependent measures immediately following the perceived stress questionnaire.

RESULTS

First, we were concerned with whether or not semester stress might influence results, so we conducted a one-way ANOVA with the treatment condition as a predictor and the perceived stress scale score as the dependent measure. The ANOVA revealed no significant differences in perceived stress levels of the students between conditions, $F_{(2,44)} = .738$, $p = ns$, thus it receives no further mention in the following analyses.

The remaining analyses were conducted using a one-way ANOVA with gender as a covariate. The model is denoted by the following equation:

Y_i = treatment + gender + treatment x gender, where Y_i is any one dependent variable.

Effects on Mood and Affect

First, we examined effects on the various mood states measured by the Profile of Mood States – Short Form. This variable is broken down into the following sub-scales: depression-dejection, anger-hostility, tension-anxiety, vigor-activity, confusion-bewilderment, and fatigue-inertia. Each was examined independently using the linear model mentioned above. Contrary to our prediction that interaction with living plants would positively affect mood, an ANOVA revealed scores on the PANAS and POMS-SF were not significantly different for participants between the plant conditions, or between the plant conditions and the control group.

Effects on Creativity

Using the same linear model, we examined the effects of plant treatment on creativity and its sub-scales: cognitive flexibility, fluency, originality, and elaboration. Contrary to our prediction that directly interacting with plants would influence creativity more positively than simply viewing pictures of plants, we found no significant differences for the overall measure of creativity or its sub-scales. In addition, there was no significant difference between the plant conditions and the control group.

Effects on Attention and Working Memory

We examined effects on cognitive performance in two ways: accuracy and median reaction times. Differences in degrees of freedom were due to lost data from malfunctions in the computer program. In partial support of our hypothesis, we found that treatment predicted performance on a mathematics task. A post-hoc LSD indicated participants performed significantly faster on the task if they were in the plant interaction condition (M = 2177.85, SD = 122.9) as compared to the control group (M = 2465.28, SD = 151.9), $F_{(2,40)} = 2.87$, $p = .07$, but no significant difference was observed between the plant and book (M = 2246.13, SD = 222.4) treatment, or the book treatment and the control group. We observed a similar effect for the motor control task, $F_{(2,41)} = 2.68$, $p = .082$, where a post-hoc LSD indicated participants performed significantly faster on the task if they were in the plant interaction condition

(M = 251.4, SD = 20.4) as compared to the control group (M = 322.7, SD = 24.4), but no significant difference was observed between the plant and book (M = 267.7, SD = 36.5) treatment, or the book treatment and the control group. See Table 3.

Table 3. Treatment by Mean Reaction Time (in seconds) of Cognitive Tasks

	Plant Interaction	Book Viewing	Control	F	p
Math	2177.85 (122.9)[a]	2246.13 (222.4)[ao]	2465.28 (151.9)[o]	2.87	.07
Motor Control	251.4 (20.4)[a]	267.7 (36.5)[ao]	322.7 (24.4)[o]	2.68	.082

Next, we examined accuracy on each of the cognitive tasks. Table 4 shows that, contrary to our prediction that participants who directly interacted with plants would show better performance on cognitive tasks, we did not see any significant differences between treatment conditions or between plant conditions and the control group.

Table 4. Treatment by Accuracy (Number correct) of Cognitive Tasks

	Plant Interaction	Book Viewing	Control	F	p
Math	83 (4.75)	86.4 (8.6)	87.8 (5.87)	.220	.80
Verbal Working Memory	89.9 (3.04)	96.1 (5.44)	98.7 (3.64)	1.79	.18
Spatial Working Memory	86 (4.21)	91.9 (7.54)	90.5 (5.04)	.361	.70
Vigilance	93.8 (3.08)	94 (5.56)	97.6 (3.93)	.325	.72
Logistical Reasoning	87.8 (3.13)	97.1 (5.66)	96.2 (3.87)	1.88	.17

DISCUSSION

This study primarily sought to determine whether ten minutes of direct interaction with plants would positively affect mood and cognitive performance as compared to simply viewing pictures of plants. The only differences we observed were for two tests, and only between the control group, which had no exposure to plants of any kind, and the plant interaction group. This is the first time a math test and a test of motor control have been examined as to whether they can be influenced by exposure to plants. Although they provide evidence that interacting directly with plants affects cognitive performance, the findings suggest that the exposure only affects the speed at which participants complete the task. Also, contrary to our predictions, task accuracy for working memory and attention tasks was unaffected by either plant treatment.

It is quite possible our sample size (N = 45) was too small to find significant differences between conditions, and the two tasks whose differences were observed were spurious. However, findings were observed in the predicted condition. But, confounding differences between the treatment groups overall could also have explained the few differences we observed. For example, the plant interaction group was exposed to natural lighting for ten minutes, while the book treatment and control group were not. Also, the plant interaction condition participants were standing and walking for ten minutes, while the book treatment and control group remained seated throughout most of the study.

STUDY 3B: EFFECTS OF ACTIVE VERSUS PASSIVE INTERACTION WITH PLANTS ON COGNITION AND MOOD

Since so many factors could have been responsible for the results in the previous study, we revised the study to control for some of them. Participants in both plant conditions were placed in identically lit rooms, although those interacting with plants had the plants set out before them on a table whereas participants in the picture condition simply had the book on the table in front of them. Also, all participants remained seated for the entire study, both during the answering of the plant questionnaire and during the administration of the dependent measures. Since we were not sure whether the results of Study 3A might be due to confounds related to the differences in conditions associated with various types of lighting, the fact that one set of participants was standing and walking around in a conservatory while the others were seated during their treatment, or a poor treatment manipulation, we decided to maintain our original treatment manipulation and control for the other confounds.

Our primary prediction was participants interacting with living plants in comparison with those looking at pictures of plants in a book would show faster reaction times on the cognitive performance tasks involving attention and working memory, higher scores on a measure of creativity, and higher scores on subjective well-being scales (more positive mood and affect).

However, since this study was deliberately conducted during two seasons, we added a prediction concerning the possible buffering influence of plant interaction on mood state. This is due to the large amount of research showing that the changing seasons, especially winter, can negatively affect a person's cognitive performance (Drake, Schwartz, Turner, & Rosenthal, 1996; Spinks & Dalgleish, 2001) and mood (Ennis & McConville, 2004; Magnusson, 2000; Murray, 2003; Nayyar & Cochrane, 1996; Rohan & Sigmon, 2000; Rosenthal, Bradt, & Wehr, 1984; Spoont, Depue, & Krauss, 1991). We predicted participants would indicate seasonal influence by higher scores on positive mood scales in fall, and higher scores on negative mood state scales in winter. We also predicted the depressing effect of the winter season on mood might be buffered by interaction with plants. Specifically, after interacting with plants, participants in the winter season but not the fall season would report higher subjective well-being (mood and affect).

METHODS

Participants

Participants were recruited from introductory psychology courses at a college in upstate New York. During the fall season, we recruited 77 participants (mean age = 19.3). Of these, 26% were male and 74% were female, 92% were undergraduates, and 21% were declared psychology majors. For the winter season, we recruited 32 participants (mean age = 18.96). Of these, 33% were male and 67% were female, 100% were undergraduates, and 6.25% were declared psychology majors. Participants were randomly assigned to one of two conditions in each season, either interaction with plants or viewing pictures of plants in a book. All students received extra credit in a specified course for their participation.

Design

The experiment was a 2 (Fall/Winter Seasons) x 2 (Living Plants/Pictures of Plants) x 3 (Levels of Self-Reported Seasonal Influence: None/Mild/Extreme) factorial design. Subject measures included a self-report of seasonal influence, as measured by the Seasonal Pattern Assessment Questionnaire (SPAQ) and semester stress, as measured by the Perceived Stress Scale (PSS).

Constructs and Measures

Independent Measure

Type of Plant Exposure. Participants were exposed to one of two conditions which required them to either interact with living plants or view pictures of plants in a book. See Illustrations 6 and 7. The plant-interaction condition room contained 12 living plants of various types, shapes, and colors. Plants were specifically chosen to have little or no scent, although there were some flowering plants. Labels were provided for each plant. Participants completed a questionnaire that required them to physically interact with the plants in order to correctly answer the questions. An identical room, without plants, was used for the book-viewing condition. Participants completed a similar questionnaire, using a plant taxonomy book called Flowering Plants of the World (1993). The book contains color drawings of plants and detailed descriptions. See Illustration 5 from Study 3A on page 52.

Illustration 6. Photo of Plant Interaction Treatment Room

Illustration 7. Photo of Picture Book Viewing Treatment Room

Dependent Measures

Dependent measures were identical to those utilized in the previous study, with the exception of the seasonality questionnaire and the cognitive performance tasks. In addition, since we were concerned with whether the administration of the mood and affect measures might flatten any effects or else jeopardize the 'ecological validity' of the study (see Isen & Erez, 2005), we randomly selected half of the participants in both conditions to be given the mood (Profile of Mood States – POMS) and affect (Positive and Negative Affectivity Scale – PANAS) self-report measures; for the other half, we did not administer this questionnaire.

Seasonality. The Seasonal Pattern Assessment Questionnaire (SPAQ) (Rosenthal, Bradt, & Wehr, 1984; Rosenthal, 1993) is used to assess seasonal influence. Three main questions on the SPAQ were utilized: (1) Seasonal Pattern: The calendar lines (representing each month of the year) outline the nature of the seasonal variations in mood and behavior. Participants outline the months of the year in which they experience different alterations in mood and behavior. Winter seasonal patterns are indicated if participants indicate they feel worst in the months between December and February. A score is calculated by totaling how many months they choose for the question of when they "feel worst"; (2) the Global Seasonality Score (GSS) measures intensity of seasonal variations in mood and behavior across the previous year as a whole. Using a five-point scale ranging from no change to extremely marked change, participants rate their degree of seasonal change in sleep length, social activity, mood, weight, appetite and energy level. A GSS score of 11 or greater indicates the possibility of SAD, scores of 8-10 indicate S-SAD or "winter blues"; and the degree to which seasonal disturbances in mood and behavior are a problem. After an answer of 'yes', participants rate whether it is mild, moderate, marked, severe, or disabling. If a participant answers 'no', they will be scored 0. If 'yes', they will be scored by how they rate their problem; mild = 1, moderate = 2, marked = 3, severe = 4, and disabling = 5 points. A choice of at least 'moderate' indicates possible SAD; S-SAD is indicated by a choice of at least ‘mild’ (p. 36, Rosenthal, 1993). The SPAQ has acceptable test–retest reliability and the six items of the GSS are both highly internally consistent, and consistent with the information reported within other sections of the SPAQ (Magnusson, 2000; Young, Blodgett, & Reardon, 2003). The SPAQ has also demonstrated good test-retest reliability in college student populations (Rohan & Sigmon, 2000).

Cognitive Performance. MiniCog is a software package developed by Stephen Kosslyn and Jennifer Shephard at Harvard University. MiniCog is designed for use on a Palm OS handheld computer and contains nine, 1-2 minute cognitive tasks that evaluate various areas of cognition. We administered the following five tests:

Vigilance: In this task, a series of small geometric shapes is presented one at a time on the screen. The set of shapes contains one target and four distractors. Because targets are presented occasionally and randomly, the test-taker must maintain concentration to detect them (see Manly, Robertson, Galloway & Hawkings, 1999), pressing one button when they see the target and another when they see the distractors.

Filtering: This task is the Stroop task (Stroop, 1935), in which participants see color names printed in different color inks (e.g., the word "red" might be printed in blue ink). In this version, the color names appear on the screen, one at a time, and the test taker is required to press the labeled button corresponding to the color of the 'ink' while ignoring the meaning of the word.

Perceptual and Motor Control: It's important to discover whether changes in response times or errors on the tests may be due simply to a slower motor response rather than other cognitive deficits. Therefore, this is a test in which a stimulus (a small oval) appears above randomly-selected keys on the Palm pilot. Users must respond by pressing the corresponding key as quickly as possible.

Verbal Working memory: This task requires participants to see a series of stimuli and respond when a stimulus appears that had also appeared two trials earlier in the sequence (this is called the "n-back" test; see Cohen et al., 1994).

Spatial Working Memory: Using the mental rotation paradigm pioneered by Shepard and Metzler (1971), pairs of stimuli are presented, with one member of the pair rotated relative to the other. Test-takers are required to try to "mentally align" one form so it is at the same angle as another, and then to decide whether the two are identical or mirror-reversals.

Setting

Participants met the researcher in the first of three identical, small laboratory rooms, where they completed measures of seasonality and perceived stress. They used the other two adjoining laboratory rooms during their treatment activity and for completing subjective well-being scales, cognitive tasks, and the creativity test.

Procedure

The study was conducted during September (fall) and February (winter). Participants were told that the study was aimed at looking at relationships between the seasons and cognitive performance. The study took approximately forty-five minutes to complete.

The participants met the researcher, filled out an extra credit form, and read and signed the consent form. The researcher explained the purpose of the study and asked for any questions. Participants were asked to fill out the Seasonal Pattern Assessment Questionnaire and Perceived Stress Scale. During this time, the researcher randomly assigned participants into treatment conditions, and placed participants in rooms corresponding to treatment condition. Participants were brought to separate but identical research rooms and given written directions and a questionnaire which required either direct interaction with plants placed on the counter in front of them (plant condition) or perusal of plants in a plant taxonomy book (book condition) to find answers. Directions informed participants that they had ten minutes to complete the task, to stay seated, not rush, but to answer the questions to the best of their ability. If they finished early, they were told to relax and wait until the researcher returned. After a timed ten-minute period, the researcher either administered the POMS-SF and PANAS scales to participants, or continued directly to the creativity task. Following this task, the researcher administered the cognitive tasks on the Palm pilot to each participant.

RESULTS

First, we were concerned with whether or not semester stress might influence results, so we conducted a one-way ANOVA with season as a predictor and the perceived stress scale score as the dependent measure. The ANOVA revealed no significant differences in perceived stress levels of the students between the two seasons, so it receives no further mention in the following analyses.

In studies of seasonality, researchers have often have used the Global Seasonality score to create categories for the degree of seasonal influence: extreme seasonal influence (indicative of Seasonal Affective Disorder), mild influence (or 'winter blues'), or no influence (taken from Kasper et al., 1989b). Based on our hypothesis that exposure to living plants would buffer seasonal effects on mood and cognition, we created a factor representing the three levels of self-reported seasonal influence. First, we separated participants into the three degrees of seasonal influence mentioned previously. We found 51% (N = 56) of participants reported suffering from extreme seasonal influence, 17% (N = 19) reported suffering from mild seasonality or winter blues, and about 32% (N = 35) indicated no influence of the seasons. We used this factor, dubbed 'self-reported seasonal influence' or SRS, in our subsequent analyses.

The analyses were conducted using a factorial ANOVA, with three possible interactions. The model is denoted by the following equation:

Yi = plant condition + season + SRS + gender + treatment:season + treatment:SRS + treatment:season:SRS, where Yi is any one dependent variable.

Effects on Mood and Affect

In this study, and based on the lack of evidence from the previous two studies, we were concerned the administration of a mood measure might flatten any effect of mood on cognitive performance, so we randomly assigned only half our participants to receive the two subjective mood measures: the Profile of Mood States – Short Form (POMS) and the Positive and Negative Affectivity Scale (PANAS). Therefore, sample sizes were reduced by half, thus, reducing degrees of freedom in the following analyses.

First, we examined effects on the various mood states measured by the Profile of Mood States – Short Form. This variable is broken down into the following sub-scales: depression-dejection, anger-hostility, tension-anxiety, vigor-activity, confusion-bewilderment, and fatigue-inertia. Each was examined independently using the ANOVA model mentioned above. In accordance with our prediction, we found that tension-anxiety increased as participants' self-reported seasonality influence (SRS) increased, $F_{(2,49)} = 2.76$, $p < .076$. The anger-hostility, $F_{(2,49)} = 3.54$, $p < .03$ and the confusion-bewilderment subscales, $F_{(2,49)} = 2.89$, $p < .068$, followed the same pattern. In addition, season directly affected confusion-bewilderment, $F_{(1,50)} = 5.37$, $p < .026$, with participants complaining of more confusion in fall ($M = 2.48$, $SD = .152$) than in winter ($M = 1.95$, $SD = .196$). Other than this finding, though, the actual season was not predictive of mood state. See Table 5.

Table 5. Mean Mood State Scores by Self-Report Global Seasonal Influence Scores

Mood and Affect Scales	Seasonal Influence by Mean Scores (sd)			*F*	p
	None N = 35	Mild N = 19	Extreme N = 56		
Negative Affect	16.9 (1.99)[a]	22.3 (3.72)[ao]	24.2 (1.89)[o]	2.99	.061
Positive Affect	32.4 (1.55)	35.7 (2.88)	31.1 (1.46)	1.05	.359
Depression-Dejection	1.51 (.209)	1.81 (.388)	2.13 (.197)	2.03	.145
Tension-Anxiety	2.00 (.198)[a]	2.27 (.368)[ao]	2.58 (.17)[o]	2.76	.075
Anger-Hostility	1.42 (.189)[a]	1.92 (.352)[ao]	2.13 (.179)[o]	3.54	.038
Vigor-Activity	2.98 (.181)	2.98 (.337)	3.03 (.171)	.063	.939
Fatigue- Inertia	2.19 (.246)	2.23 (.459)	2.67 (.233)	1.82	.176
Confusion-Bewilderment	2.05 (.169)[a]	2.27 (.314)[ao]	2.53 (.159)[o]	2.89	.067

Means (sd) in the same row with different letter designations are significantly different from one another.

However, contrary to our prediction that interaction with living plants would positively affect mood, none of the mood sub-scales of the POMS was found to be significantly different between plant conditions. The final three sub-scales, depression-dejection, vigor-activity, and fatigue-inertia, were unaffected by exposure to plants, self-reported seasonal influence, or the actual seasons. To confirm this, based on the ANOVA model, there were no significant interactions between season, plant condition, or self-reported seasonal influence.

Using our ANOVA model, we examined effects of different types of plant exposure on positive and negative affectivity. Once again, we found self-report seasonality (SRS) marginally predicted negative affectivity, $F_{(2,49)} = 2.99$, $p = .061$, whereby negative affectivity increased as self-reported seasonal influence increased. When we examined the effects on positive affectivity, we discovered no significant differences between plant treatments, seasons, or the factor pertaining to self-reported seasonal influence. See Table 5.

Lastly, based on the earlier mentioned concern about possible flattening of mood effects on cognition, we examined whether or not the administration of the POMS and the PANAS mood measures had an effect on the subsequent creativity test and cognitive measures by analyzing performance on the tasks using a one-way ANOVA with our predictor defined as a factor of whether or not participants received the mood measure. Administration of the mood measures did not affect performance on the creativity task or any of the cognitive tasks.

Effects on Creativity

Using the same factorial ANOVA model, we examined the effects of plant treatment, seasons, and self-reported seasonal influence on creativity and its sub-scales: cognitive flexibility, fluency, originality, and elaboration. We found no significant differences between plant conditions or the two seasons for the overall measure of creativity. Also, contrary to our hypothesis, responses by participants in the plant picture (book) condition (M = 13.98, SD = .832) were also found to be marginally more elaborate than those in the living plant interaction condition (M = 12.13, SD = .612), $F_{(1,109)} = 3.16$, $p < .079$. In addition, participants in fall (M = 1.64, SD = .199) created significantly less original verbal ideas than winter participants, (M = 2.48, SD = .612), $F_{(1,109)} = 8.03$, $p < .006$. There were no significant interactions between season, plant condition, or self-reported seasonal influence for overall creativity or any of the sub-scales.

Effects on Cognitive Performance

We examined effects on cognitive performance in two ways: latency or mean reaction times, and percent error. Differences in degrees of freedom were due to lost data from malfunctions in the Palm Pilot. In terms of reaction time, we found for the classic Stroop task, participants had much higher Stroop interference if they were exposed to living plants (M = 1027.76, SD = 40.82) than if exposed to pictures of plants in a book(M = 981.06, SD = 53.72), $F_{(1,109)} = 4.41$, $p < .039$. For the spatial working memory task, participants had faster reaction times in winter (M = 2523.9, SD = 244.6) than in fall (M = 2834.1, SD = 140.3), $F_{(2,105)} = 4.63$, $p < .035$.

Next, we examined percent error associated with each of the cognitive tasks. First, we found a marginally significant season x self-report seasonal influence (SRS) interaction for the vigilance task, $F_{(2,94)} = 2.75$, $p < .071$. A post-hoc LSD indicated that, in the fall only, participants reporting severe seasonal influence were significantly more accurate on the task than participants reporting either mild or no seasonal influence. Though we found no main effects of plant treatment, season, or SRS on the remaining cognitive tasks, we did find a significant plant treatment x SRS interaction for the verbal working memory task. A post-hoc LSD indicated that participants reporting mild seasonal influence, or ‘winter blues’, made significantly more errors on the task if they were in the plant picture book condition (M = 67.91%, SD = 12.86) than if they interacted with living plants (M = 21.22%, SD = 8.47), $F_{(2,105)} = 5.09$, $p < .008$. In addition, we also found a treatment x season interaction for the same verbal working memory task, $F_{(2,105)} = 2.95$, $p < .09$. Participants made more errors in the plant picture book condition (M = 53.9%, SD = 9.03) than in the living plant condition (M = 30.38%, SD = 6.77), but only in winter.

DISCUSSION

Unlike the previous study, this study had a much larger sample size, and controlled for the possible confounds of lighting and activity differences between groups. However, contrary to our main prediction that interacting with plants would positively influence cognitive performance and mood, we did not observe these differences between the plant interaction and book viewing groups. Indeed, where differences were observed, the interaction with living plants seemed a detriment to performance.

Another prediction was mood would be influenced by season, and we did find partial support from our results. Although the actual season did not significantly affect mood or affective state, participants' self-reported influence of seasonal changes did remarkably predict mood. This brings up an interesting psychological question regarding one's perception of seasonal influence, as the findings suggested that participants' perception of the how strongly they were affected by seasonal changes was directly related to how positive or negative they reported their mood as being. More specifically, if participants reported severe seasonal influence, they also reported higher scores on negative affect and negative mood scales. The scores on these scales were lower if participants recorded mild seasonal influence, and even lower if they reported no seasonal influence.

The findings of the relationship between self-reported mood and affective state, and self-reported seasonal influence, also provide a possible explanation for why we did not observe many differences in cognitive performance between the two plant conditions. The most likely explanation is our plant manipulation was not effective, due mainly to the fact the questionnaire task was too analytical and perhaps flattened any positive effect the plants may have initially had on the participant's psychological state. Another possible explanation is that the influence of having plants in the room is not any more profound than observing pictures of plants, though we cannot be sure of this since we did not have a pure control group by which to compare both plants conditions.

Finally, we predicted that interacting with plants would buffer any negative effects of the winter season on mood state. However, we saw no such moderating effects. Again, the most likely cause was a poor manipulation, which led to a lack of moderation.

SUMMARY OF RESEARCH STUDY FINDINGS

In conclusion, the findings from study one indicate that window views positively influence performance on a ten-minute creative problem solving task. Specifically, window view content containing natural stimuli influenced performance more than building stimuli, and significantly better than the no-view control group. In addition, participants with an urban view made marginally more errors on an inhibition task than those viewing either a natural scene or having no view. However, neither the view nor the view content had a significant impact on performance on a sustained attention task.

Study two determined that ten minutes of passive relaxation in a room with plants did not impact performance on a working memory task any differently than relaxing in a room containing other types of office embellishment. This study did find, however, the ten minute exposure to plants negatively influenced well-being. Participants exposed to plants expressed more negative affect and reported more physical health complaints than participants exposed to other office embellishments.

Studies 3A and 3B expanded on the ten-minute exposure to plants used in the previous studies by examining whether active involvement with plants for ten minutes would impact performance on cognitive tasks, creativity, and mood any differently than passively viewing pictures of plants in a book for the same time period. Findings from both studies indicated that mood was mainly unaffected by the type of plant exposure. In study 3A, we found participants interacting with living plants performed faster on a mathematics task and a perceptual motor control test than a control group which was not exposed to any plant stimuli, but not faster than participants viewing pictures of plants. However, creativity and cognitive task accuracy were unaffected by condition. In study 3B, we included a measure of self-reported influence of the seasons to examine whether seasonal influences in mood could be buffered by interacting with living plants. Findings indicated that mood was predicted by self-report seasonal influence; the greater the seasonal influence, the more negative the mood. Interestingly, participants interacting with living plants did better on a couple of cognitive tasks (i.e. vigilance and verbal working memory), but only if they reported mild seasonal influence, or only during a specific season. However, interacting with living plants did not buffer seasonal influences on mood. On the cognitive tasks, findings indicated that interacting with living plants negatively influenced performance on a task measuring inhibition (executive control) but otherwise, no differences were observed between conditions. In addition, overall creativity did not differ between conditions, although participants viewing pictures of plants were marginally more elaborate in their creative output than those interacting with living plants.

CHAPTER FOUR

DISCUSSION AND CONCLUSIONS

DISCUSSION OF FINDINGS

The main objective in conducting this series of research studies was to examine the effects of exposure to natural stimuli on cognition using tasks validated for assessing specific underlying attention processes. Using specific cognitive tasks, we could observe particularly which areas of attention might be influenced by exposure to either plants or natural settings: creative problem solving, inhibition, vigilance, and working memory. While conducting these studies, we were also interested in answering a few additional questions related to the effects of plant exposure. Therefore, the second objective was to determine whether natural stimuli would enhance mood as compared to other types of non-natural stimuli such as sculpture or views of buildings. The third aim of the research was to compare whether or not distinct types of exposure to natural stimuli would have different effects on cognitive performance and mood state. More specifically, we were interested in examining whether tangible interaction with living plants would influence cognition and mood differently than simply viewing pictures of plants. Finally, based on the fact one of the latter studies was conducted in two seasons, an additional objective was to assess whether or not exposure to nature would have a buffering influence on the negative impact of winter on mood state. The following table provides a summary of the research studies, the type of independent and dependent measures used in each study, and whether findings were significant or not.

Table 6. Summary of Conditions, Tasks, and Research Findings of All Studies

	Conditions	Tasks	Significant?
Study One	Window View vs. No View	Creative Problem Solving (Remote Associates Test)	Yes – better with view Yes - natural view better than control
	Natural View vs. Building vs. No View	Inhibition (Stroop)	Yes – more errors in building view
		Sustained Attention	No
Study Two	Plants vs. Objects in office	Working Memory (Backwards Digit Span)	No
		Mood/Affect (POMS/PANAS)	Yes – less NA with objects
		Optimism	No
		Mindfulness	No
		Physical Symptoms	Yes – more with plants
Study 3A	Plant Interaction in Conservatory vs. Viewing Picture Book of Plants vs. Control Group with no Plant Stimuli	Perceived Stress (PSS)	No
		Mood/Affect (POMS/PANAS)	No
		Creativity (ATTA)	No
		Mathematics	Yes – plants better than control
		Logistical Reasoning	No
		Verbal Working Memory	No
		Spatial Working Memory	No
		Sustained Attention	No
		Memory Recall	No
		Motor Control	Yes – plants better than control
Study 3B	Plant Interaction vs. Viewing Picture Book of Plants	Seasonality	Yes – seasons / moods
		Perceived Stress	No
		Creativity (ATTA)	Yes – more elaborate in book condition
		Sustained Attention	No
	– identical rooms/lighting	Inhibition (Stroop)	Yes – slower in plant interaction
		Spatial Working Memory	No
	Winter vs. Fall Season	Verbal Working Memory	Yes - more errors for book in winter
		Motor Control	No

Effects of Natural Stimuli on Cognitive Performance

In order to achieve the first objective, we chose a series of tasks used in the cognitive sciences to measure attention processes associated with inhibition, working memory, creative problem solving, and vigilance. The first three types of tasks fall under executive attention processes, however, the first two require local processing and more stringent concentration while the latter task uses global processing and greater cognitive flexibility. The vigilance task, although requiring concentration, is considered a sustained attention task and activates the same areas of the brain as executive tasks.

So, using cognitive psychology methodology, did we find executive and sustained attention processes were positively influenced by exposure to natural stimuli? Based on the research, it appears executive processes requiring greater cognitive flexibility, such as the creative problem solving task, can be positively affected by exposure to natural stimuli. More specifically, we observed that having a window view enhanced performance on the task significantly more than not having any view. In addition, having a view of a natural setting such as a forest provided a more positive influence than a view of buildings, as compared to not having a view at all (Study One). Although we did not see differences in the creativity task in the two studies examining differences between interacting with plants and viewing pictures of plants (Studies 3A and 3B), we believe this is due to a failed exposure manipulation.

Contrary to research on directed attention, we observed that performance on executive attention tasks requiring inhibition were not enhanced by exposure to natural stimuli. In the window view study (Study One), participants made more errors on the inhibition task when exposed to a window view of buildings as compared to a view of nature, but neither condition differed significantly from not having a view at all. In Study 3B, participants had higher reaction times (were slower) on the inhibition task if they directly interacted with plants as opposed to viewing pictures of them. In both of these studies, the Stroop task was utilized as a measure of inhibition. Only one other study (Faber Taylor et al., 2002) has utilized this measure, but the researchers combined this score with other measures, making it impossible to know whether this task in particular was enhanced or impaired by exposure to nature.

In addition, and also contrary to past research indicating that exposure to natural areas enhances working memory performance on the Backward Digit Span Task (Kuo, 2001; Kuo & Sullivan, 2001), we did not observe differences in performance on this same task when participants relaxed for ten minutes in a room of plants versus a room of other embellishments (Study Two). However, in the last study (Study 3B), we found that during the winter season, participants who interacted with living plants made less errors on a similar verbal working memory task (i.e. *n*-back task) than those viewing pictures of plants in a book and that participants reporting mild seasonal influence also performed better on the task if they interacted directly with plants versus viewing them in a book. However, the conclusiveness of these latter findings is suspect considering the possibility of a failed exposure manipulation. Therefore, based on the data from both studies, we still cannot conclude that working memory performance is always positively influenced by exposure to living plants.

In terms of sustained attention, or vigilance, we did not observe any influence of natural stimuli on task performance, no matter what type of exposure was utilized. As mentioned earlier, one study using similar measures did find that nature positively influenced sustained attention. However, Berto (2005) utilized a pre-post study whereby she fatigued her participants with a five minute sustained attention task, exposed them to urban or nature *pictures*, and gave them the task again. Our participants were not fatigued, had a real view, and the task lasted only two minutes. It seems that perhaps sustained attention is positively influenced primarily if an individual is suffering from some form of psychological exhaustion. As our participants were under no such mental load, we cannot assert that focused cognitive tasks requiring vigilance are influenced by simple exposures to natural stimuli. Indeed, findings by Stone and Irvine (1993; 1994) using computational and filing tasks that also require sustained concentration support this assertion. In both studies, the authors found no differences in task performance for participants who had a window view versus those without a view.

A few possible explanations exist for the divergent findings in our observations regarding executive processes requiring inhibition and working memory performance. First, based on the puzzling results observed in the studies examining active versus passive exposure to plants, we believe the exposure manipulation was not successful. Perhaps the questionnaire was too analytical and hence flattened any positive effect that may have occurred from interacting with living plants. Second, the lack of effects in some cases could be explained by small sample sizes, whereby there was not enough statistical power to observe an effect. Or else, the effect was not robust enough (i.e. low power) to have a noticeable effect on participants.

Another alternative explanation for the differences in the findings could be due to the amount of time individuals were exposed to the stimuli. In the case of the window study, perhaps the few minutes prior to the administration of the two-minute sustained and inhibition tasks was not a long enough or strong enough exposure to impact performance. However, this is unlikely considering that a difference was observed for the inhibition task. In addition, in all of the studies, participants had ten minutes to be exposed to different types of natural stimuli such as: interact with plants, look at pictures of plants, view nature from a window, or relax in a room with plants on the shelf. As creative problem solving was clearly impacted by this amount of exposure, it appears that ten minutes is enough time to produce some type of effect.

Do Distinct Types of Natural Stimuli Affect Cognition and Mood Differently?

Two of the four research studies addressed the question of whether or not different types of exposure to natural stimuli affect cognition and mood in distinct ways. In Study 3A, we found participants interacting with living plants performed faster on a mathematics task and a perceptual motor control test than a control group which was not exposed to any plant stimuli, but not faster than participants viewing pictures of plants. However, contrary to our hypotheses that tasks requiring executive attention processes (i.e. creativity, working memory, and inhibition) would be enhanced more by interaction with living plants than from viewing pictures of plants, we did not observe any significant differences between conditions on these tasks in either study.

In Study 3A, a possible explanation for the results we observed for the mathematics and motor control tasks could come from confound problems encountered during the study. In this study, participants in the plant interaction condition were in a conservatory where they were standing and walking, and exposed to natural lighting. Neither the picture viewing group nor the control group was exposed to natural sunlight, and both groups sat while completing their questionnaires. However, it is likely these confounds would have impacted other tasks, and we observed no such differences in performance on tasks measuring working memory, logistical reasoning, memory recall, or creativity. Indeed, although we eliminated both of these confounds in study four, we still did not observe any significant differences on sustained attention, working memory, and creativity tasks between the plant interaction and picture book viewing conditions. Since mathematic performance was not measured in study four, we have no way of knowing exactly why we observed significant differences in this task in study three, between the plant interaction group and the control group. However, motor control was measured in Study 3B, with no significant differences between conditions such as we observed in Study 3A. Since the sample size of Study 3B was much larger than Study 3A, a likely cause for our inability to observe consistent differences between conditions in both studies was due to a failure to successfully expose our participants so that they were validly influenced. However, since the significant difference in motor control in study 3A was found only between the plant interaction condition and the control, it may be that no difference in task performance exists between diverse types of exposure to natural stimuli. The lack of differences in performance on the motor control task between the plant interaction and picture book condition in Study 3B provides some evidence to support this idea.

It is possible the reason we did not observe differences between conditions on tasks measuring the stated attention processes is that both living plants and pictures of plants enhance performance similarly. However, if that were the case, then we should have observed differences in Study 3A between participants who interacted with plants in the conservatory and the control group who had no exposure to plants whatsoever. Since Study 3B did not have a pure control group lacking any exposure to plants, we have no way of knowing if these two types of natural stimuli have the same effect on cognitive processes associated with attention.

Finally, when we compared different types of exposure to natural stimuli, such as living plants versus pictures of plants, we did not observe significant differences in mood and affective state. We explore possible reasons for these findings below.

Does Exposure to Natural Stimuli Enhance Mood?

In all of our studies, we predicted exposure to natural stimuli would enhance subjective well-being, as represented by greater positive and lesser negative mood and affect. Our hypothesis was based on previous work which found that exposure to diverse types of natural stimuli (Barnicle & Midden, 2003; Hartig et al., 2006; Ulrich, 1979) positively affected mood state. For all four studies, we utilized one or both self-report measures of mood and affect (e.g. POMS-SF and PANAS), both which have been used in previous studies, though with mixed results.

With very few exceptions, we did not find significant differences between our natural stimuli conditions and our controls for either mood or affective state. For example, the study which examined the effects of plants and other office embellishments on subjective well-being (Study Two) revealed more negative affect and self-reported physical symptoms in the plant condition. However, it is important to look at the results of the PANAS scale itself. Results from the plant condition indicated a mean score of M = 19.5 whereas the object condition mean score was M = 13.3. Phillips and colleagues (2002) tested the factor structure of the PANAS scale on various age groups, including young adults (ages 18-22) and found for this age group, the mean score on negative affectivity for males and females was M = 19.61 and 20.08 respectively. Comparing this data to our findings reveals the plant condition score to be consistent with an average score for negative affect for this age group. Basically, the plants seemed to have no effect on participants in terms of negative affect but the objects actually caused a decrease in negative affect in participants in that condition. Reasons why the objects might have caused this decrease include: (1) they were more stimulating than the plants, and (2) they exhibited more diversity in terms of color, texture, and shape. Perhaps the complexity of the objects was enough to elicit less negativity in participants.

In terms of the lack of apparent mood alteration in the other studies, it might be that the change in mood state was very slight and not salient to the participants, and thus could not be recorded by a self-report measure of well-being. Indeed, a great deal of literature by Isen and colleagues is based on this premise. In these studies, mild inductions of positive affect are assumed to occur based on recordable performance enhancements on creative problem solving tasks (for review, see Ashby, Isen, & Turken, 1999). Considering the differences beheld in the creative problem solving task in our study, a likely explanation in terms of mood state is that participants with a view did experience a positive change in mood, but it was too mild an effect to observe *directly*. However, the indirect effect was observed for the creative problem solving task, the same task used by Estrada, Isen, and Young (1994) to measure the effects of induced positive affect on creative problem solving.

Another possibility mentioned earlier in the literature review section is the POMS and PANAS measures have often not detected differences between conditions in previous studies assessing the impact of natural stimuli on well-being (Tennessen & Cimprich, 1995; Faber-Taylor et al., 2002). Therefore, in a sense, our research substantiates previous findings, and alerts researchers to the fact that perhaps these measures are not the most useful in terms of measuring the state of individuals' mood and affect after exposure to natural stimuli.

Consequently, it may be once again our manipulation was not strong enough to impact subjective well-being. As we believe that studies 3A and 3B failed in their exposure manipulation, it would not be possible to observe differences in mood and affective state as participants' mood in the conditions was not successfully altered. However, even if the manipulation in these studies was successful, an alternative explanation could be due to the fact the pictures of plants had an equivalent effect on participants as interacting with plants. As this is the first time an attempt has been made to examine possible differences between interacting with living plants and viewing pictures of plants, we have no alternate research in which to compare the significance of our findings. Only through various replications of the research could we provide substantial foundation for the results of these last two studies.

Does Exposure to Living Plants Buffer Negative Seasonal Influence on Mood?

Since the final study of the series was conducted during two seasons (fall and winter), we were curious as to whether or not interaction with living plants could buffer the negative effects of winter on mood state. A great deal of research has observed that the changing seasons, especially winter, can negatively affect a person's mood (Ennis & McConville, 2004; Magnusson, 2000; Murray, 2003; Nayyar & Cochrane, 1996; Rohan & Sigmon, 2000; Rosenthal, Bradt, & Wehr, 1984; Spoont, Depue, & Krauss, 1991), and that exposure to plants and natural stimuli can also positively affect mood state (Barnicle & Midden, 2003; Hartig et al., 1991, Hartig, et al., 2003; Larsen et al., 1998; Ulrich, 1979). Therefore, we included a measure of self-reported influence of the seasons in this study so we might examine whether seasonal influences in mood could be buffered by interacting with living plants. As hypothesized and in keeping with results of previous season-based studies, findings indicated mood was predicted by self-report seasonal influence; the greater the seasonal influence, the more negative the mood. However, contrary to our hypothesis that interacting with living plants would buffer the negative effects of seasonal influences on mood, we did not observe differences between conditions. As mentioned in the direct examination of the effects of exposure to plants versus pictures of plants on mood, the most likely explanation for why we did not observe differences was due to a failed manipulation. However, an alternative is that neither pictures of plants or exposure to living plants has any significant effect on negative mood brought about by a long and often severe winter season in Upstate New York.

LIMITATIONS OF THE RESEARCH

The most profound limitation of this set of studies is we did not compare dependent measures from previous research to the measures used in these studies.

Observing differences or similarities in findings between our tasks (as defined by conventional cognitive psychology to test specific attention processes) and tasks used by other researchers for measuring directed attention would have provided information pertaining to the divergent validity of our measures in comparison to alternates. In addition, the results would have provided information for our argument that past studies may not have been measuring the true underlying attention processes related to directed attention. For example, one set of researchers found differences in directed attention due to the type of view from a window (natural vs. urban) using the Necker Cube Pattern Control (Tennessen & Cimprich, 1995). Our window view study would have been made stronger by using this measure alongside our two attention tasks, to examine whether or not differences would be observed using the Necker Cube, even though we did not observe any in our study. This limitation also applies to our usage of the POMS and PANAS self-report mood measures. Since the ZIPERS has been found to indicate changes in mood state in many previous studies, the addition of this measure alongside the POMS and PANAS would have provided information as to the convergent validity of our measures in terms of assessing differences in mood and affect and more information regarding changes in mood of our participants.

A second limitation of the research was the possible lack of construct validity, more specifically the possibility that the exposure manipulation used in the last two studies involving active vs. passive plant exposure was not effective. Thus, we were not able to observe significant differences between our conditions for many of the dependent measures, and for those measures that did show differences, many of the findings were counter to past research studies. Perhaps the questionnaire task was too analytical and was treated like schoolwork, thereby flattening any effect that interacting with living plants may have had on participants in that condition. Or, participants were too focused on completion of the task itself to be positively influenced by the presence of living plants on the table after the first initial exposure.

Another weakness of the research was a statistical validity concern related to low power that was due to small sample sizes. For example, the study of working memory performance only had thirty-six students separated into two conditions, and the first study of active vs. passive plant exposure had only ten participants in the control group. Finally, although the final study had a large participant base overall, when examining seasonal effects, we broke down participants into three groups based on self-reports of seasonal influence, reducing the sample size in one condition to only nineteen people. In some cases, effects were still observed regardless of the small sample sizes in conditions. Results, then, could be considered either spurious, or else positive as based on the fact that even with a small number of people, we were still able to observe a significant difference between conditions.

A final drawback to the research was the lack of a pure control group, or one that completely lacked embellishments, in two of the four studies. Comparisons were either made between active and passive exposure to plants for ten minutes (study four), or between relaxing in a room with either plants or objects on a shelf (study two). Although it would have been difficult to have a pure control group in the active vs. passive interaction study due to the simple fact that sitting in an empty room for ten minutes might have a negative effect on participants, we could have added another condition where participants answered questions for ten minutes about something not involving plants. For the study involving plants or objects in an office setting, we could have added a control condition consisting of an empty shelf. We could have then used this control as a baseline from which to compare whether plants or objects led to greater or lesser well-being and cognitive performance.

THEORETICAL IMPLICATIONS

It is interesting that although Attention Restoration Theory (Kaplan, 1995; Kaplan & Kaplan, 1989) is founded upon work conducted in the field of cognitive psychology, it is only recently that researchers in support of the theory have incorporated attention tasks validated and widely used by cognitive psychologists to measure attention processes. Since Attention Restoration Theory asserts that directed attention requires effort and inhibition from distraction, it follows from a cognitive science perspective that directed attention is a top-down executive attention process. Ergo, tasks that require inhibition, control, and/or executive processing should be influenced by exposure to natural stimuli. However, the results of this research bring into question exactly what executive, and other attention-based processes, are being influenced. For example, we found natural window views affected an executive attention task requiring greater cognitive flexibility (i.e. creative problem solving), an attribute that is counter to the need to reduce distraction. However, two studies indicated natural stimuli might have an adverse effect on executive processes requiring inhibition. In three of the studies, we did not find significant differences between conditions on a task whose underlying processes required vigilance, which requires blocking distraction to successfully complete but activates different brain areas than executive processes. In addition, in the three studies conducted using living plants, we did not see differences in those in working memory performance, which also requires greater concentration, plus more local and executive processing. However, findings from other studies do indicate that exposure to natural stimuli affects inhibition and concentration (Faber-Taylor et al., 2002), working memory (Kuo, 2001; Kuo & Sullivan, 2001) and sustained attention (Berto, 2005). Therefore, from a theoretical standpoint, our results mainly question the *kind* of top-down, executive attention processes being influenced by natural stimuli, and elucidate the possibility that attention tasks requiring greater cognitive flexibility and more global processing are also positively influenced by plants and natural views.

In addition, Attention Restoration Theory posits that exposure to natural stimuli restores directed attention fatigue. However, our research indicates that mental fatigue is not necessary in order for natural stimuli to be influential on attention task performance, at least relating to tasks requiring creative problem solving. We did not mentally exhaust our participants prior to task administration, yet natural window views did positively affect performance on a creative problem solving task. Although some participants in past research studies are assumed to have come into the study with some level of cognitive fatigue (e.g. students), it is not possible to know the exact level of fatigue or if this assumption was true. However, past studies assessing creativity support our findings as other researchers have also observed differences in creativity task performance due to exposure to plants without fatiguing their participants prior to exposure or using participants assumed to be fatigued in some way (Shibata & Suzuki, 2002; 2004; Tooley et al., 2006; Ulrich, 2004).

Although not researched here, from a theoretical perspective it is important to note that even though cognitive psychologists have discovered that certain areas of the brain activate during different types of attention tasks, the underlying mechanism of nature's effect on cognition has not been directly established by research conducted under the framework of Attention Restoration Theory. Does visual exposure to nature activate the same area(s) involved in attention? Does exposure to urban settings activate different or similar areas as exposure to nature? Are nature and/or plants compelling enough to engage involuntary attention, allowing for disengagement, and hence, restoration of directed attention? Kaplan and Kaplan (1982) theorize that attentional fatigue is "a manifestation of overuse of the neural inhibitory mechanism underlying the capacity to inhibit competing stimuli" (cited in Tennessen & Cimprich, 1995; p. 77) however no neuropsychological study has yet been conducted in order to test the possibly of an underlying neurological mechanism. S. Kaplan even states that the underlying mechanism of mental fatigue is not familiar even though the state of mind associated with the fatigue is recognizable (Kaplan, 1995). However, since our research provided additional evidence to support the role of exposure to natural settings as influential to executive functioning, and executive attention are related to activation of the pre-frontal cortex, anterior cingulate, and dopamine production, it would be feasible, using neuroimaging techniques, to test whether this area of the brain activates while engaged in a directed attention task that specifically requires executive processes, and whether or not it de-activates under restorative influences such as viewing pictures or videos of nature as compared to non-restorative pictures/videos of urban settings. Indeed, Ulrich (1993) states that current neuroscience technology such as a PET scan would enable researchers to “investigate the possible differences in brain activity during processing of natural vs. built stimuli” and that differences in locations of brain activity would provide evidence for biological responses to natural settings (pp. 124-5, in Kellert & Wilson, 1993).

CONTRIBUTIONS OF THE RESEARCH TO THE LITERATURE

One of the main contributions of this research was to provide further insight into the theoretical foundations underlying the impact of natural stimuli on attention processes. More specifically, the main objective of this series of studies was to examine whether or not exposure to natural stimuli would influence specific areas of attention processing. By using cognitive tasks known to measure the specific underlying attention processes, we were able to observe that executive processes of attention requiring creative problem solving were influenced by natural stimuli, and in a manner not yet represented in the literature. Only a few studies thus far have observed effects of natural stimuli on creative problem solving (Shibata & Suzuki, 2002; 2004) and overall creativity (Tooley et al., 2006; Ulrich, 2004), but in all cases, the research involved potted plants and/or flowers. This study provides the first evidence that window views also enhance creative problem solving, especially views containing natural content. In addition, although we did not observe significant findings, this was the first study to examine the effects of a window view and its content on sustained attention (vigilance).

A second significant addition to the literature was the exploration of the concept that interacting with plants might have varying degrees of influence on cognitive performance from simply viewing pictures of plants. Previous research studies have focused mainly on comparisons between natural and urban stimuli or between plants and lack of stimuli. With the exception of one study (office plants and/or window views: Chang & Chen, 2005), researchers have not yet directly compared different types of exposure to one another. The latter two studies in this series examined a very specific difference in engagement: whether it was active or passive. Unfortunately, our findings suggest the exposure manipulation was not effective, therefore, we were unable to observe significant effects on cognitive tasks between the two exposure types. However, this lack of finding does by no means suggest the topic should not be explored. Indeed, the possibility the treatment was effective and no differences were observed nonetheless cannot be ruled out. Only by conducting more research in this area will we be better able to illuminate any differences between various types of exposure to natural stimuli.

Finally, this research expands upon the use of working memory tasks as measures of executive attention, and provides tentative evidence that not all types of plant exposure positively affect working memory performance. Indeed, although other studies (Kuo, 2001; Kuo & Sullivan, 2001) have observed differences in working memory performance using an identical task, the studies involved long term exposure to either natural or barren areas. Even studies using alternate working memory tasks (Tennessen & Cimprich, 1995; Faber Taylor et al., 2002) where positive effects were observed are based on individuals living in a location affording longer exposure. Perhaps, in the case of working memory, ten minutes of exposure to plants does not provide a strong enough influence to produce a significant effect.

FUTURE AVENUES FOR STUDY

In examining past research, a remarkable observation is the overall positive impact of even a small exposure to natural stimuli. In fact, this exposure does not need to be direct or real; even pictures of nature seem to provide enough exposure to yield at least short-term benefits, with effects extending even to adolescents and children (Faber Taylor, Kuo, & Sullivan, 2002; Wells, 2000). In addition, Psycho-Evolutionary Theory (Ulrich, 1983, Ulrich et al., 1991) and Attention Restoration Theory (Kaplan & Kaplan, 1989) have made elegant arguments supporting nature's restorative potential, both cognitively and physiologically, and both theories have an impressive amount of empirical evidence in support.

This is not to say that further research is unwarranted. On the contrary, it seems the more indication we have of the positive influences of nature on human well-being, the more we should look at how various representations of nature affect well-being, and what kind of human response they influence. Advancements in areas such as neuroscience, cognitive psychology, environmental psychology, and computer simulation provide sophisticated techniques and measures for examining new areas of influence, or known areas of influence from another perspective. What follows are suggestions for future research and analysis.

Floral Stimuli

One aspect of plant-human interaction literature that has received little attention is research investigating the effect of flowers. While people think most often of giving flowers to show or acknowledge an emotional state, few studies have examined the influence of exposure to flowers per se (for exceptions, see Adachi, Rohde, & Kendle, 2000; Talbott, Stern, Ross, & Gillen, 1976; Tooley et al., 2006). A related avenue to explore is the effect, if any, of artificial flora. Do artificial plants and flowers have effects similar to living plants, and do such effects occur only when people do not detect the artificiality? Further, since many artificial plants do not have a scent, studies could explore sensory responses. Studies of senses like taste and smell have been found to be associated with cognition. (e.g., Baron & Bronfen, 1994; Holland, Hendriks, & Aarts, 2005) Perhaps the smell of certain flora effect changes in cognition.

Dosage Type and Level

There is a need to more closely examine dose-response, or whether the type and time period of exposure to natural stimuli influences cognition and subjective well-being to different extents. For example, does viewing five minutes of nature slides have less of an influence on mood and stress than viewing slides for ten minutes? Additional research examining different doses of exposure, such as Larsen et al.'s (1998) plant density study, would be valuable additions to the literature. Furthermore, does working with plants provide a greater (or lesser) benefit to well-being than simply viewing nature? Studies examining active versus passive exposure to nature, and subsequent effects, would be useful additions to our knowledge. Those that study active engagement with plants have done so mainly in the context of clinical populations, especially as horticultural therapy practices (for review, see Relf, 1992), but currently, effects of direct interaction with plants on more general populations have not been examined.

In addition, active involvement with nature often entails nurturing plants. Does being responsible and caring for a living plant enhance well-being differently from viewing or even working with plants in a job or school setting? A study conducted by Rodin and Langer (1977) found elderly nursing home residents showed enhanced well-being, in part due to the opportunity to nurture a plant in their room as opposed to having the staff mind it for them. Another study by Barnicle and Midden (2003) observed significant increases in positive mood for elderly nursing home patients who participated in an eight-week horticultural therapy program versus those who were told they would participate at a later time. Once again, however, both studies assessed clinical populations, making generalizations impossible.

Seasonal Relationships

Over thirty years of research has indicated changing seasons affect human well-being, especially the winter season. Winter can negatively affect a person's cognitive performance (Drake, Schwartz, Turner, & Rosenthal; 1996; Spinks & Dalgleish, 2001), mood (Ennis & McConville, 2004; Rohan & Sigmon, 2000), and positive affect (Nayyar & Cochrane, 1996). In more extreme cases, seasonal variation can lead to clinical depression, decreased physical activity, changes in appetite, increased drowsiness, decreased sociability and increased irritability and suspiciousness, as in Seasonal Affective Disorder (Rosenthal, 1993). Although the current research did not observe an influence of exposure to plants on the negative effects of winter on mood and cognition, it is possible the study manipulation failed, explaining the lack of differential findings. Therefore, other relationships between plants and seasonal influence should still be explored.

Need for Longitudinal Research and Replication

Shoemaker, Relf, and Lohr (2000) have reviewed the types of experimental designs used to examine the effects of plants and nature. Most studies utilize one of two types of designs: 1) cross-sectional, where participants receive either a plant/nature treatment or a control and differences between treatments is observed in terms of one group having ‘greater’ or ‘less’ of something, or 2) a pre-post design, where participants are given a task, such as an attention task, then given a treatment involving plant (or some other) exposure, then given the task again. The effect of treatments is measured as ‘increases’ or ‘decreases’ between the pre- and post- task. What is lacking in the literature is a third design type -- the long-term or longitudinal study. With the exception of a few studies, most of which examine clinical populations (Barnicle & Midden, 2003; Cimprich, 1993; Fjeld, 2000; Rodin & Langer, 1977; Talbot et al., 1976), the majority of research is based on short-term effects. However, it is important to discover whether plants continue to have positive effects on human health and well-being over the long term (i.e., weeks or months). Perhaps the effect on certain types of tasks continues to increase, or maybe once one becomes used to the exposure, the effects either stabilize or erode.

Although many studies have blazed new paths into the understanding of nature’s influence on cognition and mood, they often do not replicate the findings. Exceptions to this can be found in some of the studies conducted by Ulrich and colleagues (Ulrich, 1983; Honeyman, 1987; Ulrich & Simons, 1986; Ulrich et al., 1991) and in research conducted on inner-city populations (Faber Taylor, Kuo, & Sullivan, 2002; Kuo, 2001; Kuo & Sullivan, 2001). In conclusion, results of this research combined with findings from past work assessing the restorative influences of natural stimuli on cognition and mood suggest the need for additional studies in many areas, with greater consideration given to precise operationalizations of attention.

APPENDIX A
REMOTE ASSOCIATES TEST USED IN STUDY ONE

	WORDS		*SOLUTION*
Guy	Owl	Man	Wise
Soul	Busy	Guard	Body
Athletes	Web	Rabbit	Foot
Mower	Atomic	Foreign	Power
Widow	Board	Cat	Black
Arrow	Laced	Narrow	Straight
Club	Gown	Mare	Night
Cottage	Swiss	Cake	Cheese
Dew	Comb	Bee	Honey
Rocking	Wheel	High	Chair
Night	Wrist	Stop	Watch
Cream	Skate	Water	Ice
Show	Life	Row	Boat
Fountain	Baking	Pop	Soda
Hungry	Order	Belt	Money
Land	Hand	House	Farm
Shadow	Chart	Drop	Eye
Child	Scan	Wash	Brain
Cast	Side	Jump	Broad
Reading	Service	Stick	Lip
Forward	Flush	Razor	Straight

The first seven items are of moderate difficulty (from Estrada, Isen, & Young, 1994); the next seven are easy and the last seven are very difficult (from Bowden & Jung-Beeman, 2003).

APPENDIX B

PLANT INTERACTION QUESTIONNAIRE USED IN STUDIES 3A AND 3B

1. Find the plants whose leaves can be described as “spines”.
   a. Find the ‘spiny’ plant named after a certain man.

   b. Why do you think it’s called this name?

   c. What family is this plant in?

2. Find the plant named after a writing instrument. Provide the name of this plant and the family.

3. Find two members of the Piperaceae family and write their names here:

   Feel the leaves and describe how they are similar to one another.

4. Find the orchid.
   a. How many colors do you see on the flowers? How many petals are on the flowers?

   b. Do they have a scent? Describe the smell.

5. What is the dominant color of the plants in this room?

6. Choose 3 plants from the group in front of you. Provide the name of the plant, the color, and
   something unique about the plant, either about how it smells, feels, or looks.

   a.

   b.

   c.

APPENDIX C

PLANT PICTURE BOOK QUESTIONNAIRE USED IN STUDIES 3A AND 3B

1. Find the Cactaceae Family.
   a. Give the latin name of the plant that looks like a person holding up their arms:

   b. What parts of the world are these plants located in?

2. Provide the latin name of a plant on the picture plate that is flowering:

3. Find two members of the Piperaceae family and give their names and major economic use:
   a.

   b.

4. Find the Orchidaceae Family.
   a. How many colors of flowers can you find on the picture plates? How many petals can you see on the flowers?

   b. What is the range of scents for these plants, as described on the third page?

5. Go to page 313. How many flower shapes do you see?

6. Choose 3 plants in the book, each with a different color. The color can be found on any structure of the plant, e.g. leaves, flowers,etc. Provide the name of the plant, its color, and one unique thing about the plant.

   a.

   b.

   c.

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